43317

43317

WORK PLAN

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DU PONT - NEWPORT SITE
NEWPORT, DELAWARE

VOLUME II

APPENDICES A to F

Prepared for:

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Appendix A

Test Boring, Soil Sampling and Monitoring Well Installations DuPont Newport Site Newport, Delaware

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1.0 DATA OBJECTIVES

As part of the hydrogeologic study performed at the Du Pont Newport site, 27 monitoring wells were installed during June and July, 1987 (Figure 1). Twenty-one of these wells were placed into seven clusters, each consisting of a deep, an intermediate, and a shallow well. The remaining six "perimeter" wells were installed as shallow wells. One test boring was performed at each of the seven well cluster locations in preparation for the installation of the deep monitoring well (Figure 2). The seven test borings were terminated 7 to 40 feet into decomposed bedrock at.

The purpose for drilling and installing these wells was to obtain data on the vertical and horizontal gradients, permeability testing of the screened horizons, and groundwater quality assessment.

2.0 DRILLING PROCEDURES

Pennsylvania Drilling Company of Pittsburgh, Pennsylvania was subcontracted by Woodward-Clyde Consultants (WCC) to perform the test borings and install the monitoring wells.

Various drilling methods were used for the test borings and the monitoring well installations. At all of the deep and at some of the intermediate well locations, hollow stem augers were used to start the boreholes followed by mud rotary methods. At some of the intermediate well locations hollow stem augers were used to completion depth. At the shallow well locations, hollow stem augers were used to completion depth. The drilling methods used for the installation of each well are presented in Table 1.

Split-spoon samples were collected at five-foot centers from the ground surface to the completion depth for the seven test borings and the six perimeter wells. These samples are described on the boring logs presented in Appendix A-1. Sample jars were filled from each of the split-spoon samples for future reference. In addition, samples were collected for chemical analyses as discussed in the Chemistry Report, Appendix J.

All of the drilling and development equipment and tools were decontaminated using a steam cleaner between each boring.

3.0 MONITORING WELL INSTALLATIONS

A total of 27 monitoring wells were installed: 7 deep; 7 intermediate; and 13 shallow wells. The wells consist of seven well clusters containing a deep, an intermediate, and a shallow well, and six other individual shallow well locations (Figure 1). The construction of each well is detailed in the diagrams presented in Appendix A-2.

The screened interval of each well in the clusters was selected by WCC and Du Pont geologists based on review of detailed field boring logs, drawn up by WCC field geologists for the deep test borings in each cluster, as well as the borehole geophysics logs for each deep test boring. The screened intervals of the individual shallow wells were selected based on the auger cuttings.

In general, all of the wells were constructed of 4-inch I.D. Schedule 40 threaded flush joint PVC casing. All of the intermediate depth wells were constructed using (20-slot) wire wrapped stainless steel screens. All of the deep wells with the exception of those in clusters 1, 2, and 6 were also installed using the 20-slot stainless steel screens. The deep wells at clusters 1, 2, and 6 were constructed using 0.010-inch machine slotted Schedule 40 PVC screens. All of the shallow wells were constructed using 0.020-inch or 0.010-inch machine slotted Schedule 40 PVC screens. The screen type and screened intervals are summarized in Table 2.

A well-sorted silica sand pack of appropriate size for the screen was placed around the screen at each location. Depending upon the drilling method (Table 1), different methods of placing the sand pack were used. For those borings advanced via mud rotary, the sand pack was placed to the bottom of the hole and around the screen either directly through a 1.5-inch PVC tremie line or down the annulus of the borehole while water was trickled through a tremie line placed to the bottom of the hole. When wells were installed through 6.25-inch I.D. hollow stem augers, the sand pack was placed around the screen as the augers were pulled from the well. The progress of the sand pack was constantly monitored with a weighted measuring tape as the sand was placed. For the wells in which mud rotary drilling was used, some natural sediment from the borehole wall occasionally collapsed as the sandpack was added. In most instances the collapse was gradual, thereby creating a silica sand/natural sediment mixture. At MW-5B, however, a majority of the screen was covered by natural sediments.

A bentonite seal was placed above the sand pack using either bentonite pellets or, in a few cases, by pumping a thick, freshly mixed bentonite slurry (5 pounds f bentonite per gallon of potable water) down to the top of the sand pack.

A 5-percent bentonite-cement grout was then pumped from the top of the bentonite seal to the surface via a PVC tremie line. The typical grout mix was made up of 15 gallons of water, three 100-pound bags of Portland Type I cement, and 2 quarts of bentonite. In the shallowest wells the boring was backfilled using bentonite pellets to approximately three feet below ground surface.

A protective steel casing with a locking cap was cemented into the top of the borehole and around the well to protect the well casing and to prevent possible tampering. A concrete pad was installed each steel casing.

4.0 WELL DEVELOPMENT

After completion of the monitoring wells, each well was developed. As requested by Du Pont, a major objective in developing the intermediate and deep wells was to make all 14 of these wells available for pumping during an aquifer test. Therefore, the goals for the intermediate and deep well developments were:

1. maximum discharge rate
2. high efficiency
3. low sand content
4. low turbidity

These goals were achieved by efficiently using a surge block, a submersible pump, and a sand pump. The surge block was used only as long as sand was being drawn into the wells. Then a sand pump was used to remove the sand and the submersible pump was used to pump the well to remove the fine-grained sediments as well as to measure the discharge rate. This cycle was continued until no further improvement could be seen in the above factors.

The goal in developing the shallow monitoring wells was essentially to increase the well yields sufficiently enough to allow efficient purging of the wells in preparation for groundwater sampling. The shallow wells were, therefore, developed by bailing and/or pumping. Table 3 presents a summary of the development data.

Following well development, all new and pre-existing active monitoring wells were surveyed for vertical and horizontal control. The top of casing(s) and ground surface elevations are shown in Table 4.

Tables

TABLE 1

MONITORING WELLS
DRILLING METHODS
Du Pont Newport Site

Monitoring Well	Drilling Method	
MW-1A	6-1/4" I.D. HS Augers to 18 ft	
MW-1B	6-1/4" I.D. HS Augers to 74 ft	
MW-1C	4-1/4"I.D. HS Augers to 8 ft	Mud with 7-7/8" tricone roller bit to 152 ft
MW-2A	6-1/4" I.D. HS Augers to 20 ft	
MW-2B	6-1/4" I.D. HS Augers to 79 ft	
MW-2C	4-1/4" I.D. HS Augers to 60 ft	Mud with 7-7/8" tricone roller bit to 150 ft
MW-3A	4-1/4" I.D. HS Augers to 20 ft	
MW-3B	4-1/4" I.D. HS Augers to 20 ft	Mud with 7-7/8" mill tooth bit to 91 ft
MW-3C	4-1/4" I.D. HS Augers to 20 ft	Mud with 7-7/8" mill tooth bit to 145 ft
MW-4A	6-1/4" I.D. HS Augers to 20 ft	
MW-4B	6-1/4" I.D. HS Augers to 78.5 ft	
MW-4C	4-1/4" I.D. HS Augers to 30 ft	Mud with 7-7/8" mill tooth bit to 130 ft
MW-5A	3-7/8" I.D. HS Augers to 15 ft	
MW-5B	3-7/8" I.D. HS Augers with mud to 93 ft	
MW-5C	3-7/8" I.D. HS Augers with mud to 160 ft	
MW-6A	6-1/4" I.D. HS Augers to 30 ft	
MW-6B	6-1/4" I.D. HS Augers to 80 ft	
MW-6C	3-7/8" I.D. HS Augers to 25 ft	With mud to 150 ft
MW-7A	6-1/4" I.D. HS Augers to 16 ft	
MW-7B	4-1/4" I.D. HS Augers to 80 ft	Re-drilled with 6-1/4" I.D. HS Augers
WM-7C	4-1/4" I.D. HS Augers to 15 ft	Mud with 7-7/8" tricone roller bit to 115 ft
MW-8	6-1/4" I.D. HS Augers to 30 ft	
MW-9	6-1/4" I.D. HS Augers to 30 ft	
MW-11	6-1/4" I.D. HS Augers to 30 ft	
MW-13	6-1/4" I.D. HS Auger to 25 ft	
MW-14	6-1/4" I.D. HS Auger to 30 ft	
WM-15	6-1/4" I.D. to 17 ft	

Note: HS Augers indicate hollow stem augers were used

WM-44I

TABLE 2

TEST BORING AND MONITORING WELLS DRILLING AND COMPLETION DATA
Du Pont Newport Site

Well Number	Total Depth Drilled	Grout Plug Back Depth	Top of Decomposed Bedrock	Screen Interval	4-Inch Screen slot Size and Material
TB-1	152		133		
MW-1A				5.0 - 15.0	10 PVC
MW-1B				54.7 - 72.2	20 S.S.
MW-1C				118.0 - 128.0	10 PVC
TB-2	152	107	115		
MW-2A				5.0 - 15.1	10 PVC
MW-2B				62.0 - 77.5	20 S.S.
MW-2C				92.0 - 102.0	10 PVC
TB-3	147		135		
MW-3A				6.75 - 16.75	10 PVC
MW-3B				80.0 - 90.0	20 S.S.
MW-3C				117.0 - 137.0	20 S.S.
TB-4	132		125		
MW-4A				5.0 - 15.1	20 PVC
MW-4B				53.3 - 76.6	20 S.S.
MW-4C				110.0 - 120.0	20 S.S.
TB-5	162		140		
MW-5A				2.7 - 12.7	10 PVC
MW-5B				76.0 - 90.6	20 S.S.
MW-5C				113.5 - 124.9	20 S.S.
TB-6	152	118	115		
MW-6A				5.0 - 24.7	10 PVC
MW-6B				65.0 - 77.0	20 S.S.
MW-6C				100.5 - 110.5	10 PVC
TB-7	117		110		
MW-7A				5.0 - 15.1	10 PVC
MW-7B				63.0 - 78.5	20 S.S.
MW-7C				94.0 - 109.0	20 S.S.
MW-8				2.0 - 26.5	10 PVC
MW-9				5.0 - 24.7	10 PVC
MW-11				4.0 - 24.8	10 PVC
MW-13				5.3 - 25.3	10 PVC
MW-14				5.0 - 24.4	10 @ 5'-10' PVC 20 @ 10'-24.4' PVC
MW-15				5.0 - 15.1	20 PVC

Notes: All depths shown are measured in feet below ground surface.

S.S. screen material represents stainless steel.

TABLE 3

MONITORING WELLS
DEVELOPMENT RESULTS
Du Pont Newport Site

Well Number	Maximum Pumping Rate (gpm)	Semi-Equil. Pumping Level (feet)	Specific Capacity (gpm/ft)	Sand Yield	Turbidity End of Pumping	Static Water Level (feet)
MW-1A	3.5	13	1.25	trace	trace	10.2
MW-1B	17	62	0.35	trace	trace	13
MW-1C	11	103	0.11	trace	trace	9.5
MW-2A	1 +	16	0.10	slight	some	6.4
MW-2B	23	49	0.56	none	clear	8
MW-2C	23	52	0.51	none	clear	8
MW-3A	1/2	17-1/2	0.06	some		9.4
MW-3B	22	58	0.41	trace	trace	4.4
MW-3C	25	13	3.01	none	trace	4.7
MW-4A	1-1/4	15	0.45	none	slight	12.2
MW-4B	13	52	0.32	none	trace	10.9
MW-4C	10	115	0.01	trace	trace	11.8
MW-5A	7	10	1.52	slight	slight	5.4
MW-5B	15	54	0.30	trace	trace	3.85
MW-5C	15	99	0.16	slight	slight	4.0
MW-6A	1-1/2	23	0.09	trace	mod. turbid	6
MW-6C	10	99	0.11	trace	slight	6.9
MW-7A	1/2	16-1/2	0.05	some		6.2
MW-7B	18	24	1.07	trace	slight	7.2
MW-7C	17	59	0.31	trace	slight	4.6
MW-8	9	28	0.38	trace	trace	4.3
MW-9	1	25	0.06	slight	very	8.8
MW-11	1-1/4	16.6	0.13	trace	trace	7.3
MW-13	7	25	0.35	trace	some	5
MW-14	1	31	0.04	slight	very	7.6
MW-15	1 +	16	0.13	slight	very	8.5

Notes: Water levels measured from top of 4-inch PVC casing.

"Pumpage" involved use of submersible pumps, centrifugal pumps, and bailers.

WM-44I

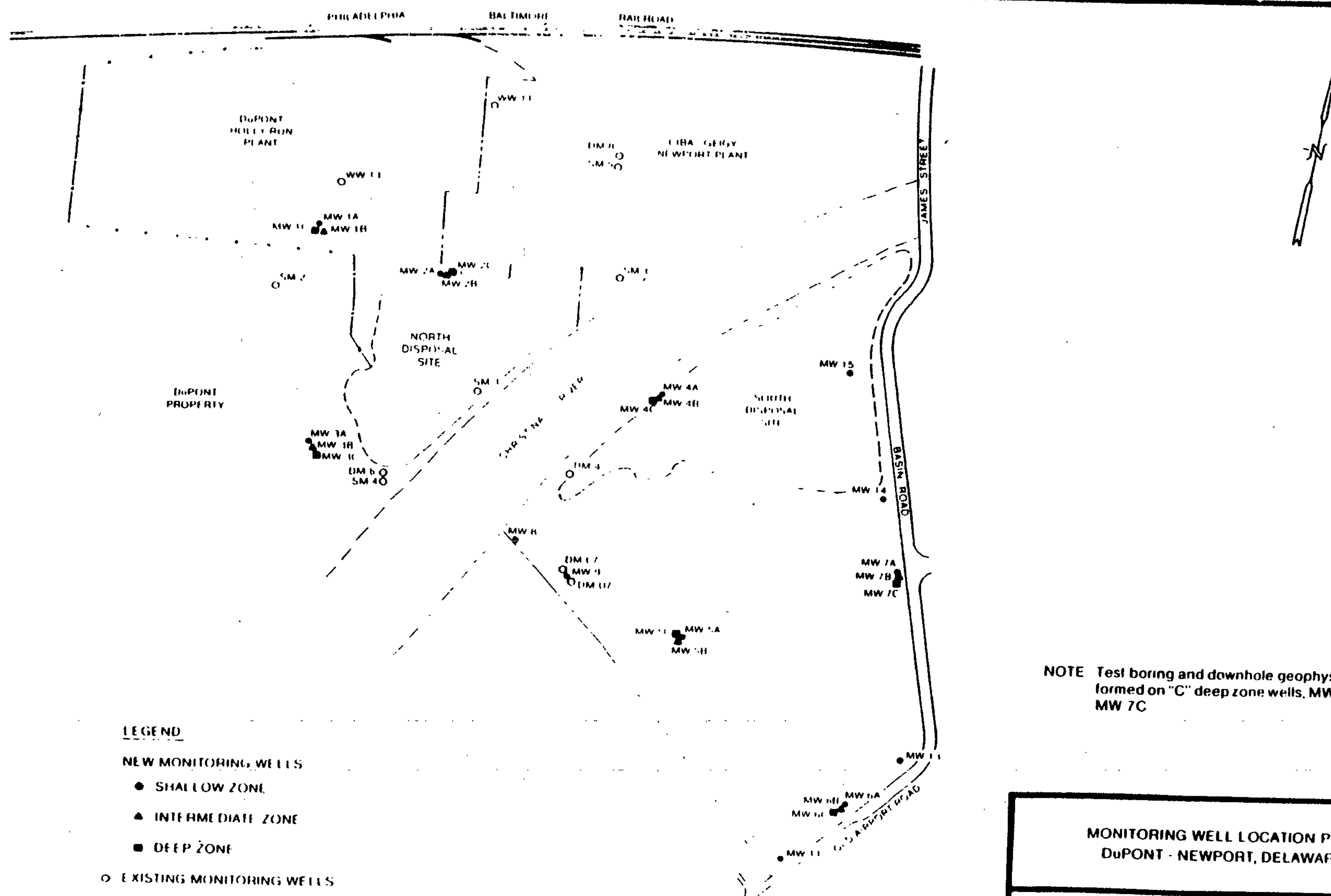
TABLE 4

COORDINATES OF MONITORING WELLS
Du Pont Newport Site

Location	COORDINATES North	COORDINATES East
DM-4	22834	17732
DM-6	22848	17102
DM-8	23891	17836
DML-7	22480	17738
DMU-7	22500	17702
MW-1A	23703	16895
MW-1B	23675	16908
MW-1C	23680	16885
MW-2A	23528	17310
MW-2B	23527	17330
MW-2C	23528	17342
MW-3A	22962	16840
MW-3B	23940	16850
MW-3C	23910	16862
MW-4A	23092	18065
MW-4B	23080	18050
MW-4C	23065	18035
MW-5A	22260	18114
MW-5B	22247	18100
MW-5C	22261	18085
MW-6A	21663	18625
MW-6B	21651	18645
MW-6C	21640	18647
MW-7A	22458	18868
MW-7B	22443	18868
MW-7C	22420	18868
MW-8	22605	17542
MW-9	22490	17720
MW-11	21479	18438
MW-13	21810	18862
MW-14	22723	18820
MW-15	23156	18720
SM-1	23495	17930
SM-2	23500	16740
SM-3	23130	17433
SM-4	22825	17098
SM-5	23890	17828
WW-11	25001	17518
WW-13	23847	16975

WM-441

Figures



NOTE Test boring and downhole geophysical performed on "C" deep zone wells, MW-1C thru MW 7C

LEGEND

NEW MONITORING WELLS

- ● SHALLOW ZONE
- ▲ INTERMEDIATE ZONE
- ■ DEEP ZONE

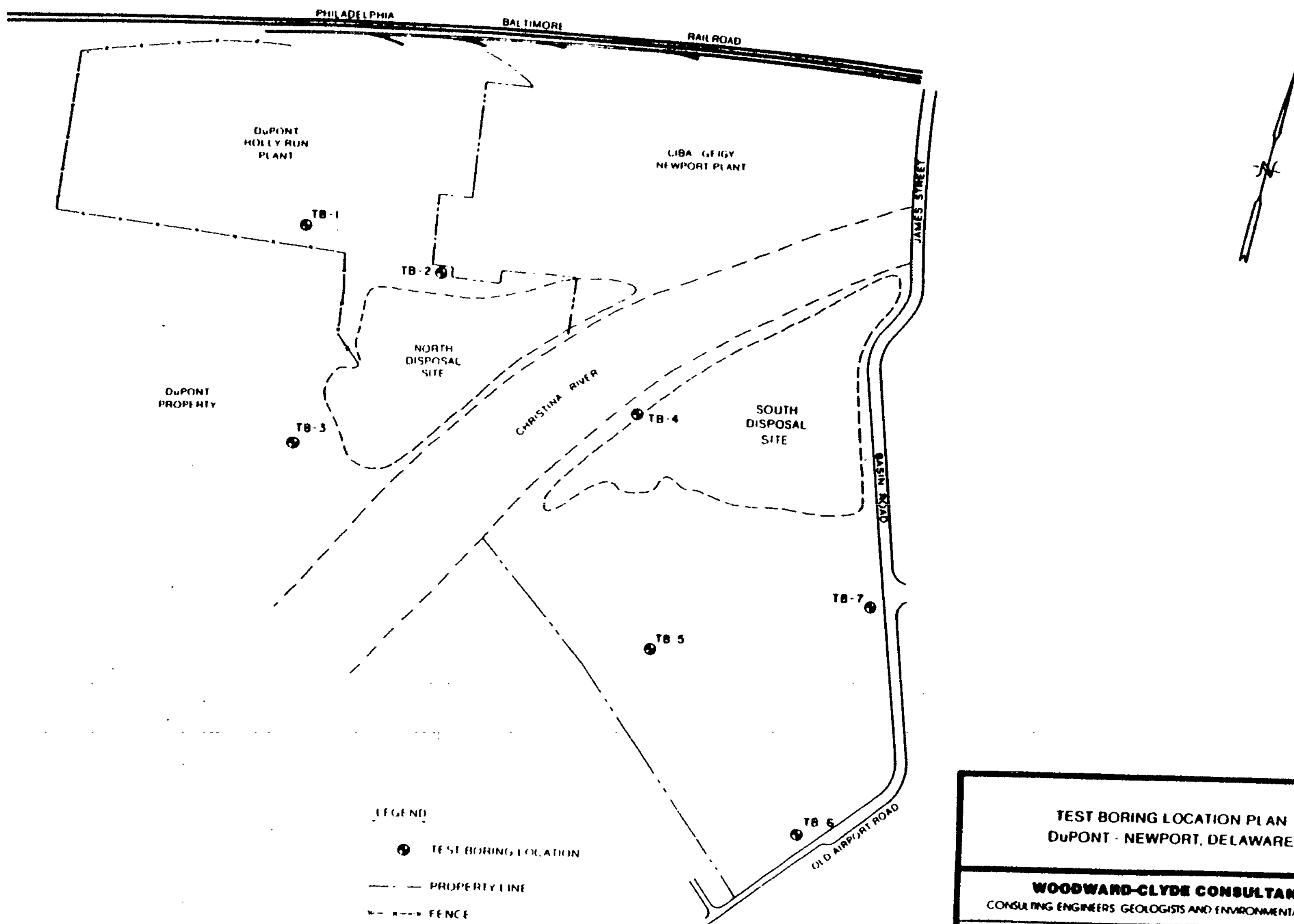
○ EXISTING MONITORING WELLS

MONITORING WELL LOCATION PLAN
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS

Drawn by T P	SCALE IN FEET 0 400	Date 9/3/87
Checked by R T G		No. 86C2076-2

FIGURE 1



TEST BORING LOCATION PLAN
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	T P	SCALE IN FEET 0 — 400	Date	9/2/87
Checked by	R T G		Job	88C2076-2

FIGURE 2

Appendix A-1

LOG of BORING No. TB-1

DATE 6/18-25/87 SURFACE ELEVATION 20.59 LOCATION

DEPTH, ft.	DESCRIPTION	ELEVATION
0	Brown organic SILT and fine SAND with a trace of gravel and coarse to medium sand	19.8
	Brown fine sandy silty CLAY	
5		15.4
	Gray and brown mottled silty CLAY with a lense of medium to fine sand	
10	- becomes orange and gray mottled with a trace of well rounded gravel	9.2
	Gray to orange-brown micaceous coarse to fine SAND	
15		5.6
	Orange and brown mottled CLAY underlain by organic brown-black to gray silty clay	3.6
	Gray coarse to fine SAND with limonite	
20	- with well rounded quartz gravel	
25	- becomes yellow-brown	
30	- and coarse to fine gravel, micaceous	
		-14.4
35	Brown, yellow-brown, red-brown, light brown mottled micaceous medium to fine SAND and SILT	
	- with fine quartz and feldspar gravel and thin lenses of red-brown clay	
40	- becomes red-brown, and clayey	
	- becomes yellow-brown mottled with red clay	
45		-24.4
	Pink, yellow-brown, and light gray mottled fine sandy silty CLAY	

Completion Depth 152 Feet Water Depth ~25 Feet Date 7/22/87

Project Name DuPont Newport Project Number 87C2665-1A

LOG of BORING No. TB-1

DATE 6/18-25/87 SURFACE ELEVATION 20.59 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
45			-24.4
		Red-brown and yellow-brown medium to fine SAND and silty CLAY	
50		- becomes fine sand and clay with light gray	
55		- becomes light gray	
			-39.4
60		Yellow-brown streaked with light gray medium to fine SAND underlain by a yellow-brown coarse to fine sand	-40.4
		Light gray micaceous fine SAND and silty CLAY	
65			-44.9
		Light gray coarse to fine quartz SAND	
		becomes fine sand and clay	
		grades to a coarse to fine sand and clay then to a light gray and yellow-brown banded fine sand and clay	
70		returns to a light gray coarse to fine sand	
		becomes yellow-brown medium to fine sand with silty clay	
75		becomes coarse to fine quartz sand with a trace of fine gravel and pockets of light gray clay	-55.2
		becomes red medium to fine sand with thin layers of yellow-brown	
80		Red with very thin layers of light gray micaceous fine SAND and silty CLAY	-60.6
		becomes light gray silty clay and fine sand	
		becomes yellow-brown, red, and light gray interbedded clayey medium to fine sand	
85			-65.1
		Red, yellow-brown, and light gray stiff silty CLAY	
		Yellow-brown CLAY and fine SAND, changing to a light gray	-69.4
90		Red, purple, and tan mottled hard silty CLAY, becoming more purple with depth	

Completion Depth 15[illegible] Feet Water Depth ~25 Feet Date 7/22/87

Project Name DuPont Newport Project Number 87C2665-1A

LOG of BORING No. TB-1

DATE 6/18-25/87 SURFACE ELEVATION 20.59 LOCATION

DEPTH, ft.	DESCRIPTION	ELEVATION
90	Red, purple, and tan mottled hard silty CLAY, becoming more purple with depth	
	becomes light gray fine sand and clay	-74.4
95	Yellow-brown clayey medium to fine SAND	
	becomes orange-brown	
100	becomes yellow-brown, interbedded with red-brown and light gray mottled fine sandy clay	
		-84.4
105	Light gray and yellow-brown silty CLAY and fine SAND mottled with very stiff purple CLAY	
	becomes red, yellow-brown, and light gray silty clay	-89.6
110	Yellow-brown coarse to fine quartz SAND	-90.7
	becomes red-brown	
	becomes yellow-brown to light gray	
	Red, yellow-brown, and light gray varved micaceous silty CLAY	
115	becomes red and light gray mottled with lenses of yellow-brown medium to fine sand	
120	0.3 feet of light gray silty coarse to fine sand	-100.1
	becomes red, yellow-brown, and light gray fine sand and clay	
	Red and yellow-brown coarse to fine SAND with small pockets of light gray clay	
125	with quartz gravel	
		-109.4
130	Red-brown and purple mottled fine SAND and silty CLAY	
135		-114.4
	DECOMPOSED METAMORPHIC BEDROCK	

Completion Depth 152 Feet Water Depth 25 Feet Date 7/22/87

Project Name DuPont Newport Project Number 87C2665-1A

OG of BORING No. TB-1

DATE 6/18-25/87 SURFACE ELEVATION 20.59 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
135			DECOMPOSED METAMORPHIC BEDROCK Brown, green-brown, and light gray CLAY and gravelly coarse to fine quartz SAND with veins of yellow-green quartz and pockets and foliations of light gray clay		
140			becomes foliated blue-gray and green-brown micaceous fine sandy clay		
145					
150			becomes dark gray with a vertical vein of granitic material	-131.4	

Completion Depth 152 Feet Water Depth ~ 25 Feet Date 7/22/87

Project Name Dupont - Newport Project Number 87C2665-1A

LOG of BORING No. TB-2

DATE 6/19-27/87 SURFACE ELEVATION 16.98 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
0			Light brown silty fine SAND		
			becomes light gray-brown with coarse sand		
5				12.0	
			Gray-green micaceous silty CLAY		
			becomes light orange-yellow with terra cotta chips		
10			becomes gray-green, then gray and orange mottled, then red-brown		
15			becomes gray to orange, then dark gray		
				0.7	
			Orange and red slightly micaceous coarse to fine quartz SAND and GRAVEL		
20				-3.0	
			Gray-orange silty CLAY	-3.7	
			Yellow-brown and red-brown coarse to fine quartz SAND and GRAVEL		
25			slightly micaceous		
30			becomes brown-orange	-13.5	
			Light gray gravelly coarse to fine quartz SAND and silty CLAY becomes mottled with yellow-brown and red-brown		
35				-18.0	
			Yellow-brown clayey fine SAND to red-brown sandy CLAY		
40			becomes red and yellow-brown mottled		
			becomes yellow to light yellow clayey fine sand		
45					

Completion Depth 152.0 Feet Water Depth - Feet Date 8/11/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-2

DATE 6/19-27/87 SURFACE ELEVATION 16.98 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
45			
50		Yellow-brown medium to fine quartz SAND	-33.0
55		Red-brown slightly micaceous clayey coarse to fine SAND and GRAVEL	-38.0
		- becomes yellow-brown with light yellow-white vugs of clay	
60		-becomes light gray, yellow-brown, and red-brown mottled with some clay lenses	
		- becomes light gray medium to fine sand with black minerals and some iron staining	
65		-becomes yellow to yellow-white clayey coarse to fine sand and gravel with clay lenses	
		-becomes medium to fine sand	
		- becomes yellow-brown coarse to fine sand and gravel with light gray streakes of clay	
70		-becomes light gray interbedded with black minerals, no gravel	
75		-interbedded with light gray clay	
80		-becomes medium to fine sand with bands of black minerals	-63.2
		Red-brown to yellow-brown CLAY	
85		-becomes dark red, red-brown, red, and light gray mottled	
90		Light yellow medium to fine SAND mottled with red and light gray clay streaks	-73.0

Completion Depth 152.0 Feet Water Depth - Feet Date 8/11/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-2

DATE 6/19-27/87 SURFACE ELEVATION 16.98 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION
90			-becomes light gray	
95			-becomes yellow, to yellow-brown, and light gray with 0.2 ft. of coarse sand and pink mottling	
100			-becomes light gray coarse to medium sand - becomes orange-red to tan and clayey - becomes light yellow to light gray medium to fine sand - becomes light yellow gravelly coarse sand - becomes yellow-orange with light gray clay lenes	-88.0
105				-88.8
			Black peat with quartz grains	
			Light gray clayey quartz SAND	-93.0
110			Red-brown stiff CLAY with coarse quartz sand	-98.0
115			DECOMPOSED METAMORPHIC BEDROCK Light green foliated weathered schist with mica, quartz, and kaolinite and red banding	
120				
125				
130			-with increasing mica content	
135				

Completion Depth 152.0 Feet Water Depth - Feet Date 8/11/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-2

DATE 6/19-27/87 SURFACE ELEVATION 16.98 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
135					
140			-foliations nearly vertical		
145					
150				-135.0	

Completion Depth 152.0 Feet Water Depth - Feet Date 8/11/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-3

DATE 7/9-13/87 SURFACE ELEVATION 10.27 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
0		Yellow-brown silty SAND	
5		becomes yellow-brown to gray and micaceous	
			0.3
10		Gray mecaceous CLAY	
		becomes gray-green and sandy, mottled with iron stains	-1.1
		Gray-green micaceous medium to fine SAND with black staining at 11.6 feet	
			-4.7
15		Gray to gray-green micaceous sandy CLAY mottled with iron staining	-5.4
		Brown-orange stained micaceous quartz coarse to fine SAND and GRAVEL,	
		no gravel	
20		becomes sand and gravel	
			-11.2
		Yellow-brown micaceous sand, CLAY	
			-14.7
25		Light gray and yellow-brown clayey coarse to fine SAND and GRAVEL	-15.9
		Yellow-brown and red CLAY	
			-19.7
30		Yellow-brown and light gray clayey coarse to fine SAND and GRAVEL with vugs of clay	
35		becomes medium to fine sand	
		returns to clayey sand and gravel with limonite	
			-29.7
40		Yellow-brown and red fine sandy CLAY with quartz gravel	-30.0
		Light gray clayey coarse to fine SAND and quartz GRAVEL with black minerals throughout	-30.7
		Red, yellow-brown and light gray mottled sandy CLAY	
45			

Completion Depth 147.0 Feet Water Depth - Feet Date 7/22/87

Project Name Du Pont Newport Project Number 87C2665-1A

Woodward·Clyde Consultants

AR301036

LOG of BORING No. TB-3

DATE 7/9-13/87 SURFACE ELEVATION 10.27 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
45		Red, yellow-brown, and light gray mottled sandy CLAY	
50		-becomes red, brown, and light gray mottled	
			-44.7
55		Yellow-brown, light gray, and red-brown medium to fine quartz SAND	-46.7
		grades to a red-brown and light gray clayey SAND to sandy CLAY	
			-49.7
60		Red and red-brown medium to fine quartz SAND with coarse sand and clay lenses	
65		-becomes red-brown and yellow-brown with fractured quartz coarse sand, yellow-brown clay vugs, and mica	
70		-becomes clayey coarse to fine sand including red clay lenses	
75		-yellow-brown and red mottled	-65.33
		Red and yellow-brown mottled CLAY	
			-69.7
80		Yellow-brown and red mottled clayey medium to fine SAND with clay vugs and limonite	
85		-becomes yellow-brown, light gray, and brown with coarse sand	
90		-becomes micaceous with black mineral rich bands	

Completion Depth 147.0 Feet Water Depth - Feet Date 7/22/87

Project Name Du Pont Newport Project Number 87C2665-1A

Woodward-Clyde Consultants

AR301037

LOG of BORING No. TB-3

DATE 7/9-13/87 SURFACE ELEVATION 10.27 LOCATION

DEPTH, ft.	DESCRIPTION	ELEVATION
90		
95	Yellow-brown and light gray sandy CLAY 0.5 ft. of clayey medium to fine sand becomes red-purple and light gray sandy clay	-84.7
100	becomes yellow-brown and light gray	-89.9
	Yellow-brown clayey medium to fine SAND	-91.4
	Purple CLAY	
105	Yellow-brown medium to fine SAND with lenses of light brown and pink clay lenses	-94.7
110	Yellow-brown and red-brown medium to fine SAND interbedded with yellow-brown, red, and light brown mottled clayey SAND becomes yellow-brown to olive quartz sand	-99.7
115	becomes light brown clayey sand with white and red-white mottled clay lenses	
120	Yellow-brown medium to fine SAND with vugs of white clay	-109.7
125	Interbedded yellow-brown coarse to fine SAND, light brown to light olive and yellow-brown and red mottled sandy CLAY, and yellow-brown medium to fine SAND	-114.7
130	becomes yellow-brown, red, and light gray coarse to fine sand interbedded with light gray and red clay lenses	-121.3
135	Olive coarse to fine SAND with clay lenses	

Completion Depth 147.0 Feet Water Depth - Feet Date 7/22/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-3

DATE 7/9-13/87 SURFACE ELEVATION 10.27 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
135			Olive coarse to fine SAND with clay lenses	-129.7	
140			DECOMPOSED METAMORPHIC BEDROCK Gray-green to brown-green foliated schist including quartz sand, mica, and clay		
145				-136.7	
150					

Completion Depth 147.0 Feet Water Depth - Feet Date 7/22/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-4

DATE 6/30-7/7/87 SURFACE ELEVATION 12.36 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION
0			Light brown silty SAND with concrete and asphalt fragments at surface	
5			-becomes black silty soupy material	
10				1.9
			Green silty CLAY	0.9
			Dark gray medium to fine SAND	
15				-2.6
			Dark gray slightly micaceous silty CLAY	
20				
25				-13.7
			Dark gray slightly micaceous clayey medium to fine quartz SAND with clay lenses	
30			- becomes dark gray - becomes green-tan stiff sandy clay - becomes light tan slightly micaceous clayey sand	
35				-22.6
			Light orange stained brown micaceous coarse to fine quartz SAND and GRAVEL	
40			-becomes dark brown to black and less micaceous - becomes yellow-orange and clayey	
45			-becomes red-brown to yellow medium to coarse quartz sand	

Completion Depth 132.0 Feet Water Depth - Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

Woodward-Clyde Consultants

AR301040

LOG of BORING No. TB-4

DATE 6/30-7/7/87 SURFACE ELEVATION 12.36 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
45			
50		Red-orange and yellow-orange and light gray mottled sandy CLAY with clay lenses	-37.6
55		Yellow-orange and red-orange mottled clayey coarse to fine quartz SAND and GRAVEL with clay lenses	-42.6
60		- becomes light yellow clay interbedded with quartz sand and gravel, with a red-brown clay lense -becomes red-orange clayey coarse to fine sand and gravel -becomes light yellow and less clayey, no gravel	
65		-becomes red-brown to yellow-brown and clayey	
70		0.2 ft. of black soft silty CLAY underlain by 0.5 ft. of red-brown medium to fine clayey quartz SAND - becomes sandy clay - becomes yellow-brown and light gray clayey sand	-57.6
75		Yellow-brown medium to fine SAND with yellow and red vugs of clay	-62.6
80		-becomes yellow-brown, no clay	-68.2
		Yellow to red stained coarse to fine quartz SAND and GRAVEL interbedded with red-white vugs of clay - becomes red-orange	
85		-becomes white to yellow-orange and clayey	-73.6
		Orange to red-orange silty CLAY	
90		-becomes red-white and white mottled and stiff with orange fractures	

Completion Depth 132.0 Feet Water Depth - Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

Woodward·Clyde Consultants

LOG of BORING No. TB-4

DATE 6/30-7/7/87 SURFACE ELEVATION 12.36 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
90					
95			-becomes light gray and sandy		
			-becomes pink clay with white clay		
100			-becomes gray and stiff		
				-92.6	
105			Gray clayey medium to fine quartz SAND interbedded with peat	-93.8	
			Gray stiff CLAY		
110			-becomes dark gray and organic		
			- becomes light gray and sandy		
				-102.6	
115			Light green-white medium to fine quartz SAND with a few clay lenses		
				-107.6	
120			Gray to light green to yellow-brown stiff CLAY		
			- becomes yellow-orange medium to fine sand underlain by a sandy clay		
				-112.6	
125			DECOMPOSED METAMORPHIC BEDROCK		
			Yellow-brown, foliated, weathered schist with mica, quartz, and clay minerals present		
130				-119.6	
135					

Completion Depth 132.0 Feet Water Depth - Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-5

DATE 7/7-11/87 SURFACE ELEVATION 2.38 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
0			Dark brown-gray medium to fine SAND with a trace of organics		
5			-becomes brown and slightly micaceous		
10			Brown micaceous coarse to fine SAND	-7.6	
15			-with coarse to fine gravel		
20			-becomes gray-brown with black minerals, no gravel		
25			-with fine gravel and vugs of clay		
30			Red-brown and yellow-brown mottled stiff CLAY	-27.6	
35			-becomes red-brown clay mottled with light gray fine sandy clay		
40			-and light yellow		
45				-42.6	

Completion Depth 161.8 Feet Water Depth ~6 Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-5

DATE 7/7-11/87 SURFACE ELEVATION 2.38 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
45			Red-brown mottled with light gray clayey SAND with vugs of clay		
50			-mottled with yellow-brown		
55			-becomes red, brown, and yellow-brown mottled, and red-brown and purple mottled followed by light gray		
60			-becomes red-purple to light gray		
65			-becomes yellow-brown then changes to red-white and light gray sandy clay		
70			-becomes purple and light gray mottled clayey sand to light yellow-brown clay, grading to a red-brown fine sandy clay		
75			-becomes purple clayey sand and red-brown coarse sand underlain by light gray and red clayey fine sand		
80			Red-brown coarse to medium SAND with a fine gravel seam	-77.6	
			-becomes red, light gray, and yellow-brown mottled clayey fine sand		
85			-becomes gray and light gray layered silty medium sand		
			-becomes yellow-brown		
			-becomes gray with black minerals		
90			- becomes gray and light olive-gray coarse to medium sand underlain by light gray silty fine sand		

Completion Depth 161.8 Feet Water Depth ~6 Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

AR301044

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LOG of BORING No. TB-5

DATE 7/7-11/87 SURFACE ELEVATION 2.38 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION
90			Grades to yellow-brown to olive-brown	-89.3
			Red-brown and yellow-brown mottled silty CLAY	
95				
100			-becomes light gray to white with red and olive sand inclusions	
			-becomes red and olive-brown	
105			-becomes light gray silty clay with purple sand inclusions	
110				-107.6
			Light gray to gray clayey SAND	
115				-113.8
			Light gray silty medium to fine SAND	
120			-becomes coarse to fine sand	
125				-122.6
			Purple CLAY becomes black lignite with pyrite nodules	-123.7
130			Light gray to white silty micaceous medium to fine SAND with fine gravel and silica flour	
135			-becomes white and olive silty fine sand and silica flour	

Completion Depth 161.8 Feet Water Depth ~6 Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-5

DATE 7/17-11/87 SURFACE ELEVATION 2.38 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
135					
				-137.6	
140			DECOMPOSED METAMORPHIC BEDROCK Yellow-green foliated schist with mica and quartz		
145					
150			- becomes olive and light gray		
155			-becomes light olive to light gray		
160			-becomes gray	-159.4	
165					

Completion Depth 161.8 Feet Water Depth ~6 Feet Date 8/12/87

Project Name Du Pont Newport Project Number 87C2665-1A

LOG of BORING No. TB-6

DATE 6/26-30/87 SURFACE ELEVATION 4.70 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
0		Brown micaceous fine SAND and SILT, with a trace of organics	
5		- very micaceous	
10			- 5.7
		Brown to dark brown coarse to fine SAND and GRAVEL, with a trace of cobbles and silt	-10.3
15		Brown silty fine SAND	-11.3
		Brown coarse to fine SAND and GRAVEL	
20			
25			-20.9
		Yellow-brown and light gray micaceous silty medium to fine SAND	
30			-25.7
		Red firm silty CLAY	
35		- becomes red-brown and stiff	
		- becomes light gray and yellow-brown mottled fine sandy clay	
40		- becomes red-brown and light gray soft silty clay	-36.3
		Light gray and brown fine SAND and silty CLAY	
45			-40.3
		Brown micaceous medium to fine SAND	

Completion Depth 151.8 Feet Water Depth ∿ 6 Feet Date 8/11/87

Project Name DuPont Newport Project Number 87C2665-1A

LOG of BORING No. TB-6

DATE 6/26-30/87 SURFACE ELEVATION 4.70 LOCATION

DEPTH, ft.	DESCRIPTION	ELEVATION
45	Brown micaceous medium to fine SAND	-41.8
	Red-brown silty CLAY and fine SAND	
50	- becomes clayey fine sand - with yellow-brown and light gray banding	
55	- becomes red-brown - becomes yellow-brown clayey medium to fine sand with layers of light gray clay and coarse to fine sand	
60	- becomes light gray clayey fine sand with yellow-brown and red-brown lineations - becomes red-brown and yellow-brown mottled silty clay - becomes silty clay and fine sand mottled with light gray	
65	- becomes light gray and brown mottled	-61.6
	Light gray medium to fine SAND to silty fine sand	
70	- becomes light gray, violet/pink, and yellow-brown bands of micaceous gravelly coarse to fine sand	
75	- becomes light gray coarse to fine sand and clay interbedded with silty fine sand	
		-75.3
80	Red-brown soft micaceous silty CLAY - becomes light gray and yellow-brown varved fine sandy clay	-76.1
	Light gray, red-brown and yellow-brown layers of silty medium to fine SAND	-80.3
85	0.3 ft. of red-brown, yellow-brown, and light gray soft silty CLAY underlain by a micaceous clayey fine SAND	
90	- becomes silty clay and fine sand	-86.2

Completion Depth 151.8 Feet Water Depth ~ 6 Feet Date 8/11/87

Project Name DuPont Newport Project Number 87C2665-1A

LOG of BORING No. TB-6

DATE 6/26-30/87 SURFACE ELEVATION 4.70 LOCATION

DEPTH, ft.	SAMPLES	DESCRIPTION	ELEVATION
90			-86.2
		Green-brown coarse to fine SAND with thin layers of light gray fine sand and silty clay and limonite; grades to a medium to fine sand	-90.3
95		Light gray and brown fine sandy silty CLAY 0.4 ft. of yellow-brown and light gray silty fine sand underlain by a fine sand and silty clay	
100			-96.4
		Yellow-brown medium to fine SAND interbedded with light gray silty fine sand	
105		Becomes brown micaceous coarse to fine sand with a trace of silt and fine gravel becomes yellow-brown and light gray and clayey becomes dark brown to brown, with a trace of silt	-105.3
110		Red-brown and light olive layers of fine SAND and silty clay; becomes a light olive silty CLAY with a fracture having a dip of 30°	-110.3
115		DECOMPOSED METAMORPHIC BEDROCK Olive-green fine sandy silty clay with foliations having a dip of 30°	
120		With coarse quartz sand	
125		Becomes blue-gray and olive-green in color	
130			
135			

Completion Depth 151.8 Feet Water Depth ~ 6 Feet Date 8/11/87

Project Name DuPont Newport Project Number 87C2665-1A

LOG of BORING No. TB-6

DATE 6/[redacted]-30/87 SURFACE ELEVATION 4.70 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION	
135					
140			with fracture having a dip of 50°		
145					
150				-147.1	

Completion Depth 151.8 Feet Water Depth ~ 6 Feet Date 8/11/87

Project Name DuPont - Newport Project Number 87C2665-1A

Woodward-Clyde Consultants

LOG of BORING No. TB-7

DATE 7/6-10/87 SURFACE ELEVATION 4.11 LOCATION

DEPTH, ft.	DESCRIPTION	ELEVATION
0	Dark brown and brown organic silty CLAY	3.3
	Brown fine sandy SILT, trace medium to coarse sand and gravel	2.5
5	Dark gray soft CLAY	
		- 6.0
10	Brown micaceous medium to fine SAND	- 6.6
	Brown coarse to fine SAND and GRAVEL	
15	with a trace of cobbles	
20		
		-20.9
25	Orange-brown micaceous medium to fine SAND with coarse sand	
		-25.9
30	Mottled red-brown and light gray fine sandy silty CLAY	
35	with yellow-brown	
40	no fine sand, red-brown in color with a trace of yellow-brown	
		40.9
45	Mottled yellow-brown and light gray micaceous fine SAND	

Completion Depth 117 Feet Water Depth ∿ 6.5 Feet Date 7/23/87

Project Name DuPont Newport Project Number 87C2665-1A

AR301051

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LOG of BORING No. TB-7

DATE 7/6-10/87 SURFACE ELEVATION 4.11 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION
45			Mottled yellow-brown and light gray micaceous fine SAND	-42.0
			Mottled yellow-brown, light gray, and red-brown stiff silty CLAY	
50			– with a trace of fine sand, trace light gray	
				-50.9
55			Red-brown and yellow-brown fine SAND and silty CLAY with seams of yellow-brown medium to fine sand	
			– 0.3 ft of coarse to fine sand	
60			– becomes light gray underlain by brown fine sand and silty clay	
			– becomes brown silty clay with a trace of fine sand	
			becomes brown, yellow-brown, and light gray layered fine SAND with a trace of silty clay and thin layers of limonite	-60.9
65			Yellow-brown and light gray with a trace of red coarse to fine SAND, grades to a white clayey coarse to fine quartz SAND and GRAVEL	
				-65.9
70			Yellow-brown medium to fine SAND, trace silt and gravel	
			– with a 0.3 ft seam of red-brown and light gray mottled fine sand and silty clay	
			– becomes light gray and yellow-brown with seams of light gray clay, no gravel	
75			– becomes a light gray fine sand	-71.5
			Light gray and yellow-brown silty coarse to fine SAND	
80			– brown with a trace of fine gravel	-76.8
			Light olive and light gray micaceous silty CLAY with a trace of fine sand	
			– and gravelly coarse to fine sand	
			– becomes light olive silty clay, with a trace of fine sand and red clay	
85			– becomes light olive and light gray fine sand and silty clay	
			– becomes light olive silty clay with a trace of fine sand, changing to a mottled red and light gray and then to a light gray	-85.9
90				

Completion Depth 117 Feet Water Depth ~ 6.5 Feet Date 7/23/87

Project Name DuPont Newport Project Number 87C2665-1A

LOG of BORING No. TB-7

DATE 7/6-10/87 SURFACE ELEVATION 4.11 LOCATION

DEPTH, ft.	SAMPLES		DESCRIPTION	ELEVATION
90			Light olive with a trace of red and light gray medium to fine SAND with seams of coarse to fine sand and pockets of clay	- 90.9
95			Brown coarse to fine quartz SAND with a trace of fine gravel and silt, changes to a yellow-brown	- 91.9
			Mottled yellow-brown and light gray fine SAND and silty CLAY	- 95.9
100			Mottled light-olive and light gray silty CLAY with lenses of fine sand and clay	-100.9
105			Olive clayey fine SAND becomes silty micaceous medium to fine sand	
110			With seams of light olive and light gray silty clay	-107.4
			DECOMPOSED METAMORPHIC ROCK coarse to fine sand-sized quartz granules yellow-brown to olive clayey matrix	
115			Light gray and olive colored with angular quartz granules throughout in a light gray clayey matrix, banded with schisty foliations having dips of approximately 45° in opposite directions.	-112.3
120				

Completion Depth 116.4 Feet Water Depth ~ 6.5 Feet Date 7/23/87

Project Name DuPont - Newport Project Number 87C2665-1A

LOG of BORING No. MW-8

DATE 6/30/87 SURFACE ELEVATION 4.80 LOCATION

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0			Dry brown silty fine sand with gravel	1.8				
			Wet brown medium to fine sand with gravel	-3.2				
10			Wet dark gray clay with a trace of silt					
20				-19.2				
			Wet dark gray sand with gravel	-25.2				
30			Note: All soil samples used to construct this boring log were collected from the auger flights as the boring was advanced					

Completion Depth 30 Feet Water Depth ∿ 2 Feet Date 6/30/87
Project Name DuPont, Newport Site Project Number 87C2665

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AR301054

WCC

LOG of BORING No. MW-9

DATE 7/7/87 SURFACE ELEVATION 9.21 LOCATION

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0			Soft brown silty clayey fine sand —becomes more clayey	3.2				
			Soft gray plastic silty clay					
10				-5.79				
			Very soft gray fine sandy clay					
20								
30				-20.8				
			Note: All soil samples used to construct this boring log were collected from the auger flights as the boring was advanced					

Completion Depth 30 Feet Water Depth - Feet Date 7/7/87

Project Name DuPont, Newport Site Project Number 87C2665

Woodward-Clyde Consultants

AR301055

LOG of BORING No. MW-11

DATE 6/29/87 SURFACE ELEVATION 6.34 LOCATION

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0			Dry brown silty sand					
			-becomes a moist medium to fine sand					
			-becomes wet					
			-with gravel					
10								
20				-13.7				
			Wet gray clay	-15.7				
			Wet brown medium to fine sand					
30				-23.7				
			Note: All soil samples used to construct this boring log were collected from the auger flights as the boring was advanced					

Completion Depth 30 Feet Water Depth ∿ 3 Feet Date 6/29/87

Project Name DuPont, Newport Site Project Number 87C2665

LOG of BORING No. MW-13

DATE 6/26/87 SURFACE ELEVATION 4.10 LOCATION

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0			Dry brown silty clay	1.1				
			Moist dark gray silty clay -becomes wet -with sand	-7.9				
10			Wet brown sand with gravel	-21.5				
20			Note: All soil samples used to construct this boring log were collected from the auger flights as the boring was advanced					
30								

Completion Depth 25.6 Feet Water Depth ∿ 3 Feet Date 6/26/87

Project Name DuPont, Newport Site Project Number 87C2665

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AR301057

LOG of BORING No. MW-15

DATE 7/7/87 SURFACE ELEVATION 10.73 LOCATION

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0			Light tan silty medium to fine sand	7.7				
			Wet black silty medium to fine sand	-6.3				
10								
20			Note: All soil samples used to construct this boring log were collected from the auger flights as the boring was advanced					

Completion Depth 17 Feet Water Depth ∿ 3 Feet Date 7/7/87

Project Name DuPont, Newport Site Project Number 87C2665

AR301058

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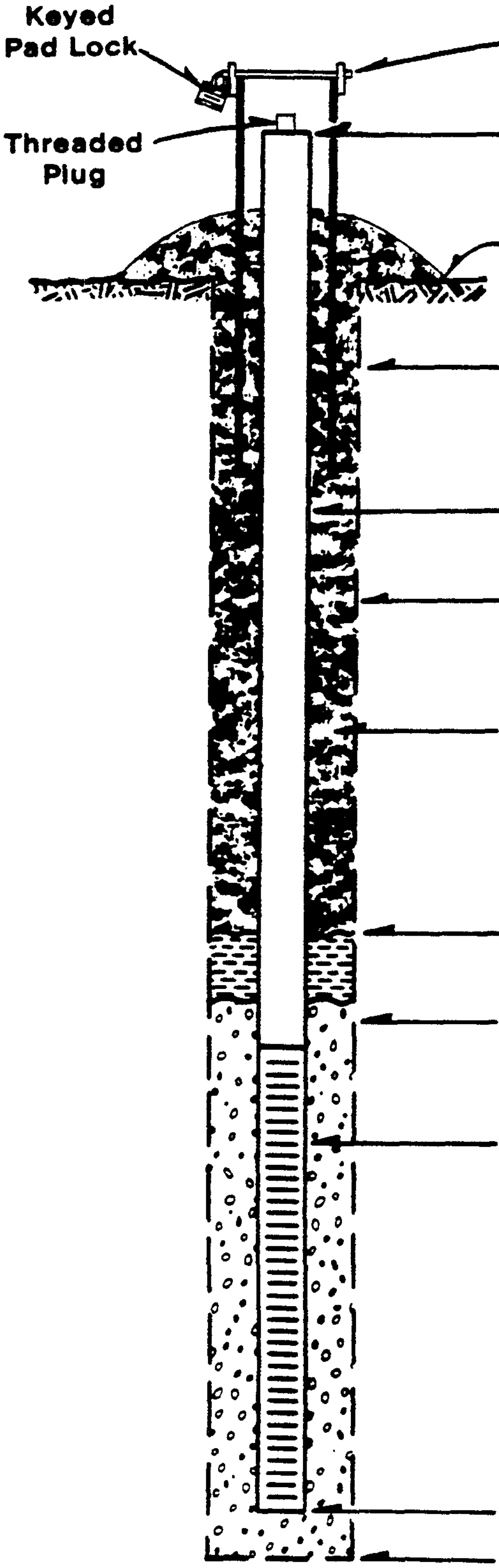
WCC

Appendix A-2



Elevation of top of surface casing: 23.05 ft

Elevation of top of riser pipe: 22.72 ft

Ground Elevation: 20.46 ft

I.D. of surface casing: 0.50 ft
Type of surface casing: steel
5 ft total length

I.D. of riser pipe: 0.33 ft
Type of riser pipe: flush threaded SCH 40 PVC

Diameter of borehole: 0.83 ft

Type of backfill: Cement

Type of seal: Bentonite Pellets
Depth to top of seal: 0.5 ft

Depth to top of sand pack: 3.5 ft

Depth to top of screen: 5.0 ft
Type of screened section: 0.010 inch
slotted SCH 40 PVC

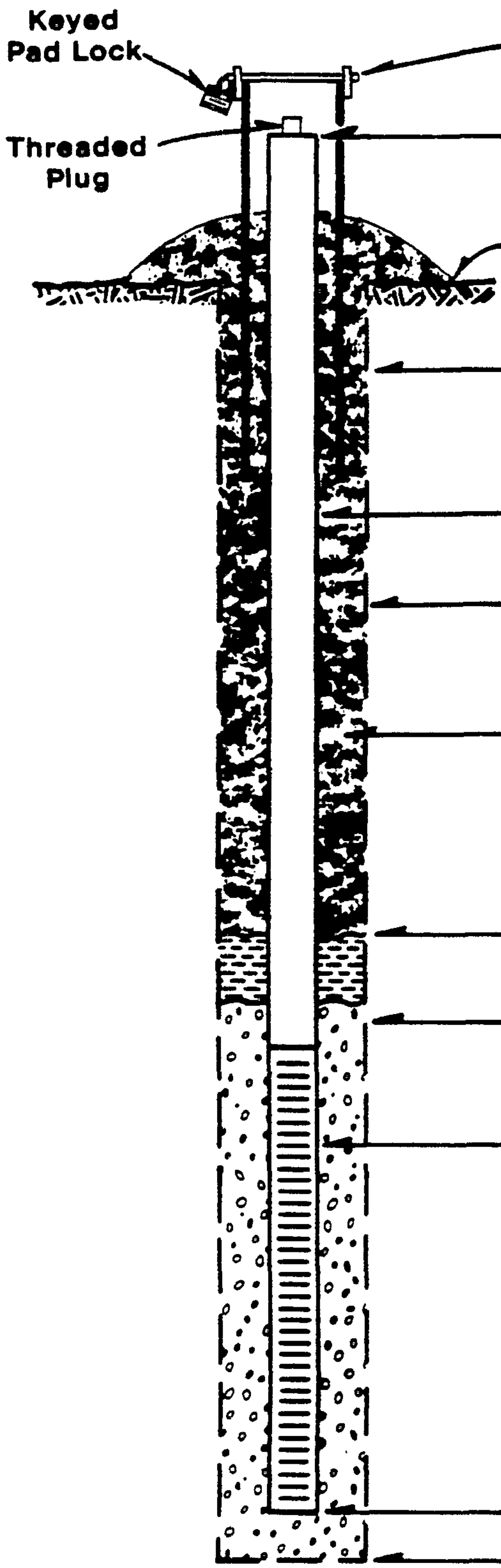
I.D. of screened section: 0.33 ft

Depth to bottom of well: 15.0 ft
Depth of borehole: 18.0 ft

REPORT OF MONITORING WELL NO. MW-1A

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO

AR301060



Elevation of top of surface casing: 23.12 ft

Elevation of top of riser pipe: 22.74 ft

Ground Elevation: 20.36 ft

I.D. of surface casing: 0.50 ft

Type of surface casing: steel

5 ft total length

I.D. of riser pipe: 0.33 ft

Type of riser pipe: flush threaded SCH 40 PVC

Diameter of borehole: 0.83 ft

Type of backfill: Cement/Bentonite Grout

Type of seal: Bentonite Pellets

Depth to top of seal: 48.5 ft

Depth to top of sand pack: 50.6 ft

Depth to top of screen: 54.7 ft

Type of screened section: 0.020 inch

Wire wrapped stainless steel

I.D. of screened section: 0.33 ft

Depth to bottom of well: 72.2 ft

Depth of borehole: 74.0 ft

Note: Centralizer set at 45 ft below ground surface

REPORT OF MONITORING WELL NO. MW-1B

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO

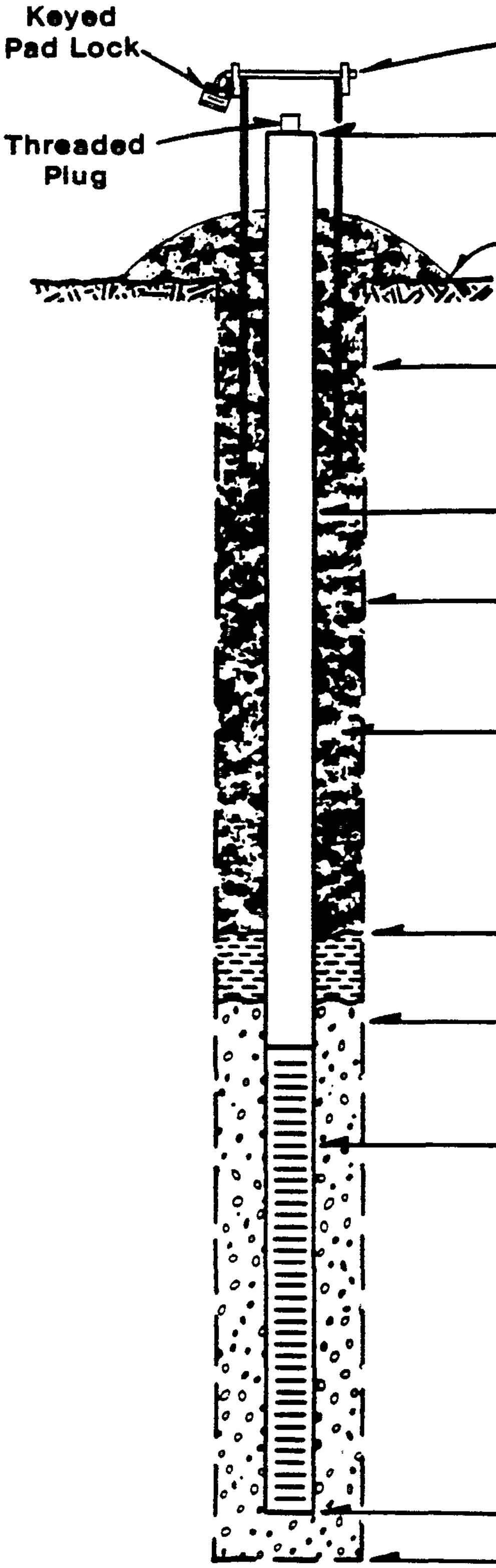
Elevation of top of surface casing	23.04 ft
Elevation of top of riser pipe	22.74 ft
Ground Elevation	20.59 ft
I.D. of surface casing	0.50 ft
Type of surface casing	steel 5 ft total length
I.D. of riser pipe	0.33 ft
Type of riser pipe	flush threaded SCH 40 PVC
Diameter of borehole	0.67 ft
Type of backfill	Cement/Bentonite Grout
Type of seal	Bentonite Pellets
Depth to top of seal	112.0 ft
Depth to top of sand pack	115.7 ft
Depth to top of screen	118.0 ft
Type of screened section	0.010 inch slotted SCH 40 PVC
I.D. of screened section	0.33 ft
Depth to bottom of well	128.1 ft
Depth of borehole	130.0 ft

Note: Centralizers at 113 ft and 60 ft below land surface

REPORT OF MONITORING WELL NO. MW-1C

DRAWN BY	CHECKED BY:	PROJECT NO:	DATE:	FIGURE NO
DG	JB	87C2665-1B	8/27/87	

AR301062



Elevation of top of surface casing: 19.39 ft

Elevation of top of riser pipe: 18.76 ft

Ground Elevation: 16.43 ft

I.D. of surface casing: 0.50 ft
Type of surface casing: steel
5 ft total length

I.D. of riser pipe: 0.33 ft
Type of riser pipe: flush threaded SCH 40 PVC

Diameter of borehole: 0.83 ft

Type of backfill: Bentonite Pellets

Type of seal: Bentonite Pellets
Depth to top of seal: 0.5 ft

Depth to top of sand pack: 4.0 ft

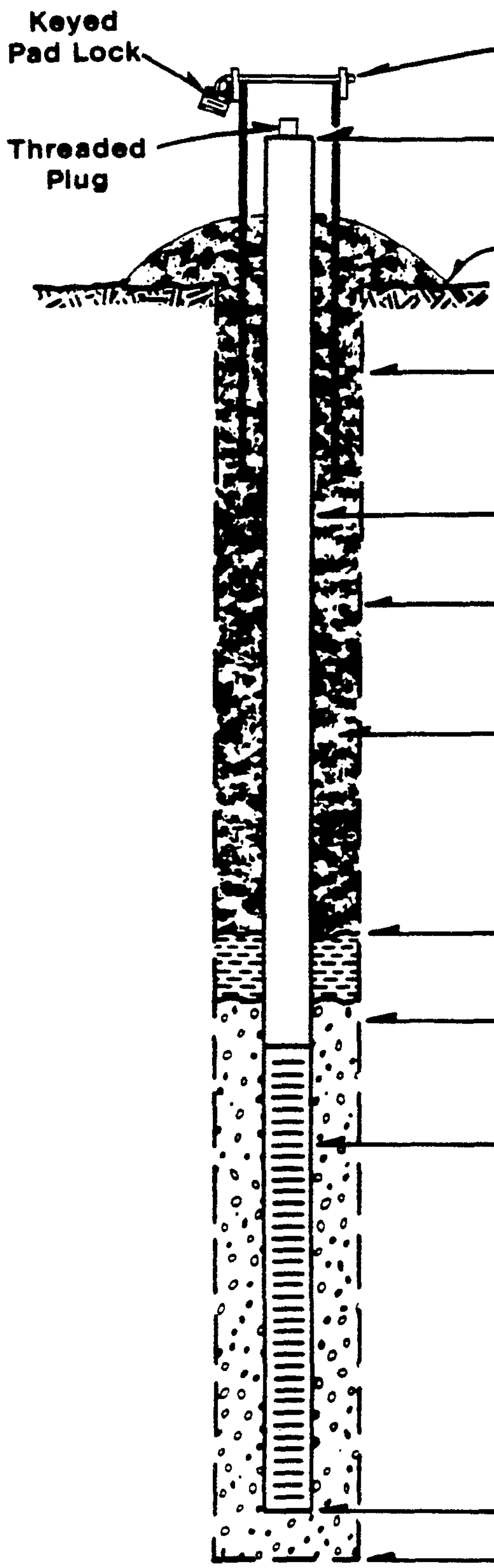
Depth to top of screen: 5.0 ft
Type of screened section: 0.010 inch
slotted SCH 40 PVC

I.D. of screened section: 0.33 ft

Depth to bottom of well: 15.1 ft
Depth of borehole: 16.0 ft

REPORT OF MONITORING WELL NO. MW-2A

DRAWN BY	CHECKED BY	PROJECT NO	DATE	FIGURE NO
DG	JB	87C2665-1B	8/27/87	



Elevation of top of surface casing 18.94 ft

Elevation of top of riser pipe 18.76 ft

Ground Elevation 16.35 ft

I.D. of surface casing 0.5 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Slurry

Depth to top of seal 49.0 ft

Depth to top of sand pack 57.0 ft

Depth to top of screen 62.0 ft

Type of screened section 0.020 inch
Wire wrapped stainless steel

I.D. of screened section 0.33 ft

Depth to bottom of well 77.5 ft

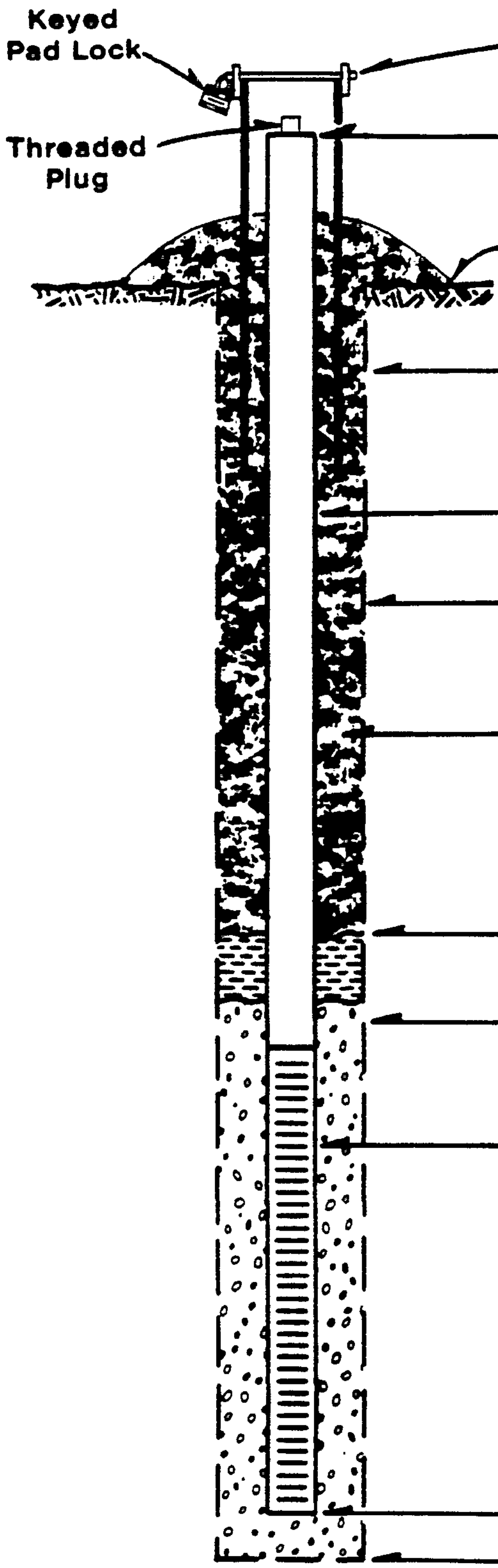
Depth of borehole 79.0 ft

Note: Centralizers set at 32.0 ft and 52.0 ft below land surface

REPORT OF MONITORING WELL NO. MW-2B

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO.

AR301064



Elevation of top of surface casing 19.49 ft

Elevation of top of riser pipe 19.07 ft

Ground Elevation 16.98 ft

I.D. of surface casing 0.50 ft
Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft
Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.67 ft

Type of backfill Cement/Bentonite Grout

Depth to top of seal (Bentonite) 73.0 ft
Depth to bottom of seal (Bentonite) 78.0 ft

10 ft of natural sand settled

Type of seal Bentonite
Depth to top of seal 88.0 ft

Depth to top of sand pack 89.5 ft

Depth to top of screen 92.0 ft
Type of screened section
0.010 inch slotted SCH 40 PVC

I.D. of screened section 0.33 ft

Depth to bottom of well 102.0 ft
Depth of borehole 152.0 ft

Note: Borehole grouted with cement/bentonite grout to 108.5 ft
Centralizers set at 42 ft and 72 ft below ground surface

REPORT OF MONITORING WELL NO. MW-2C

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO

Elevation of top of surface casing 14.21 ft

Elevation of top of riser pipe 13.84 ft

Ground Elevation 11.45 ft

I.D. of surface casing 0.50 ft
Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft
Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.67 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets
Depth to top of seal 2.0 ft

Depth to top of sand pack 4.3 ft

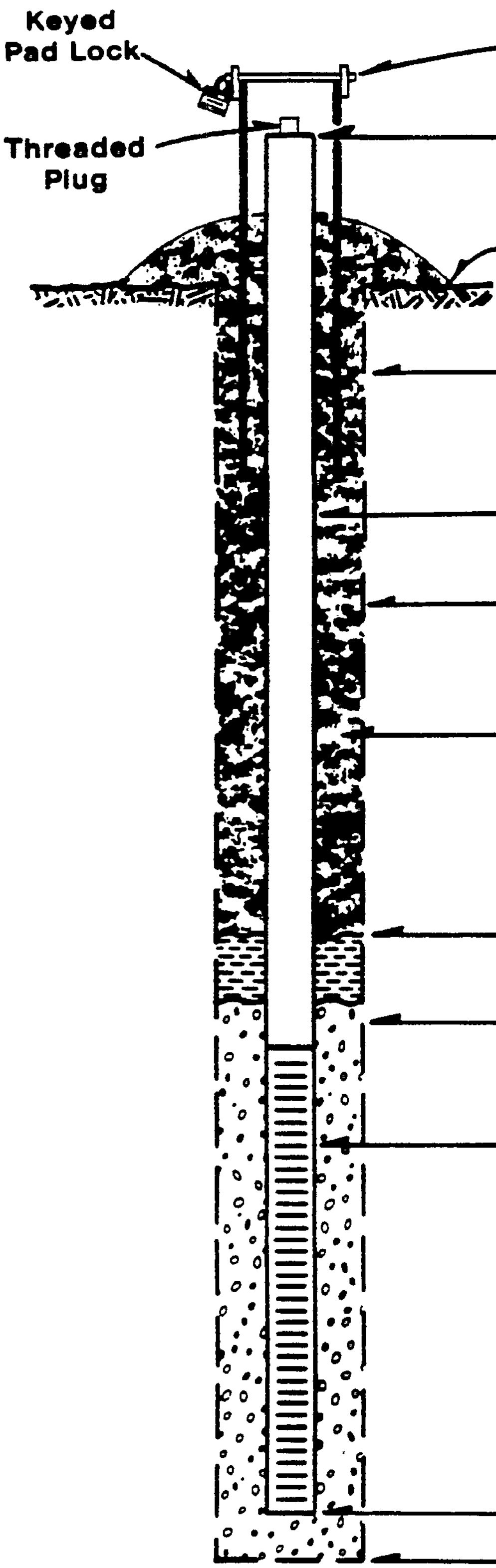
Depth to top of screen 6.75 ft
Type of screened section 0.010 inch
slotted SCH 40 PVC

I.D. of screened section 0.33 ft

Depth to bottom of well 16.75 ft
Depth of borehole 17.0 ft

REPORT OF MONITORING WELL NO. MW-3A

DRAWN BY: D G	CHECKED BY: J B	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO



Elevation of top of surface casing 13.97 ft

Elevation of top of riser pipe 13.64 ft

Ground Elevation 10.98 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.67 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets

Depth to top of seal 72.0 ft

Depth to top of sand pack 76.0 ft

Depth to top of screen 80.0 ft

Type of screened section 0.020 inch
wire wrapped stainless steel

I.D. of screened section 0.33 ft

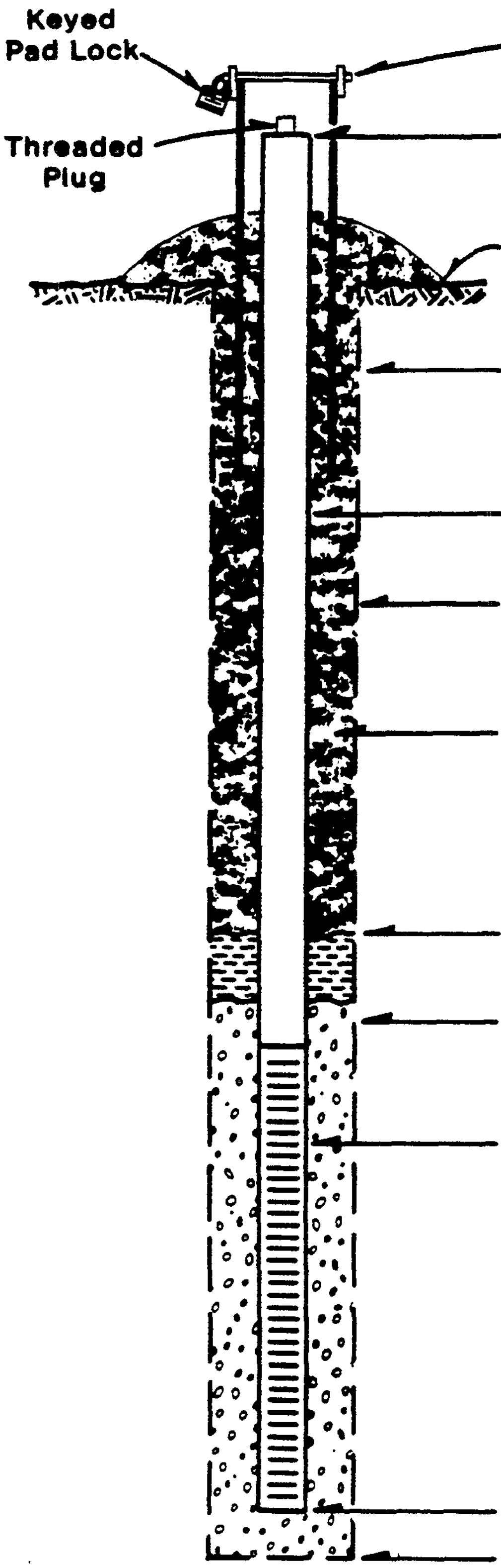
Depth to bottom of well 90.0 ft

Depth of borehole 91.0 ft

Note: Centralizers set at 39 ft and 79 ft below ground surface

REPORT OF MONITORING WELL NO. MW-3B

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO



Elevation of top of surface casing 13.09 ft

Elevation of top of riser pipe 12.78 ft

Ground Elevation 10.27 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.67 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets

Depth to top of seal 108.0 ft

Depth to top of sand pack 113.0 ft

Depth to top of screen 117.0 ft

Type of screened section 0.020 inch
wire wrapped stainless steel

I.D. of screened section 0.33 ft

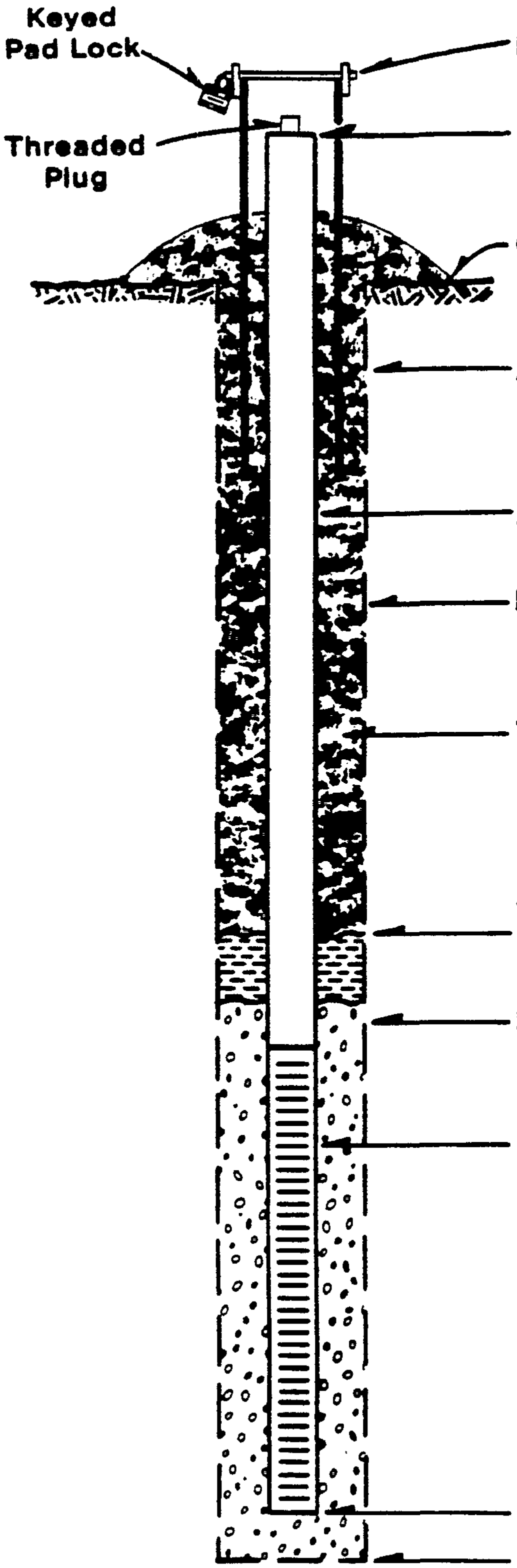
Depth to bottom of well 137.0 ft

Depth of borehole 147.0 ft

Note: Centralizers set at 77 ft and 107 ft below ground surface

REPORT OF MONITORING WELL NO. MW-3C

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: [illegible]	FIGURE NO:



Elevation of top of surface casing 16.00 ft

Elevation of top of riser pipe 15.70 ft

Ground Elevation 13.32 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Bentonite Pellets

Type of seal Bentonite Pellets

Depth to top of seal 0.5 ft

Depth to top of sand pack 4.0 ft

Depth to top of screen 5.0 ft

Type of screened section
0.020 inch slotted SCH 40 PVC

I.D. of screened section 0.33 ft

Depth to bottom of well 15.1 ft

Depth of borehole 20.0 ft

REPORT OF MONITORING WELL NO. MW-4A

DRAWN BY	CHECKED BY	PROJECT NO	DATE	FIGURE NO
D G	J B	87C2665-1B	8/27/87	

Woodward-Clyde Consultants

Elevation of top of surface casing 15.24 ft

Elevation of top of riser pipe 14.94 ft

Ground Elevation 12.69 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Slurry

Depth to top of seal 46.0 ft

Depth to top of sand pack 52.2 ft

Depth to top of screen 53.3 ft

Type of screened section
0.020 inch wire wrapped stainless steel

I.D. of screened section 0.33 ft

Depth to bottom of well 76.6 ft

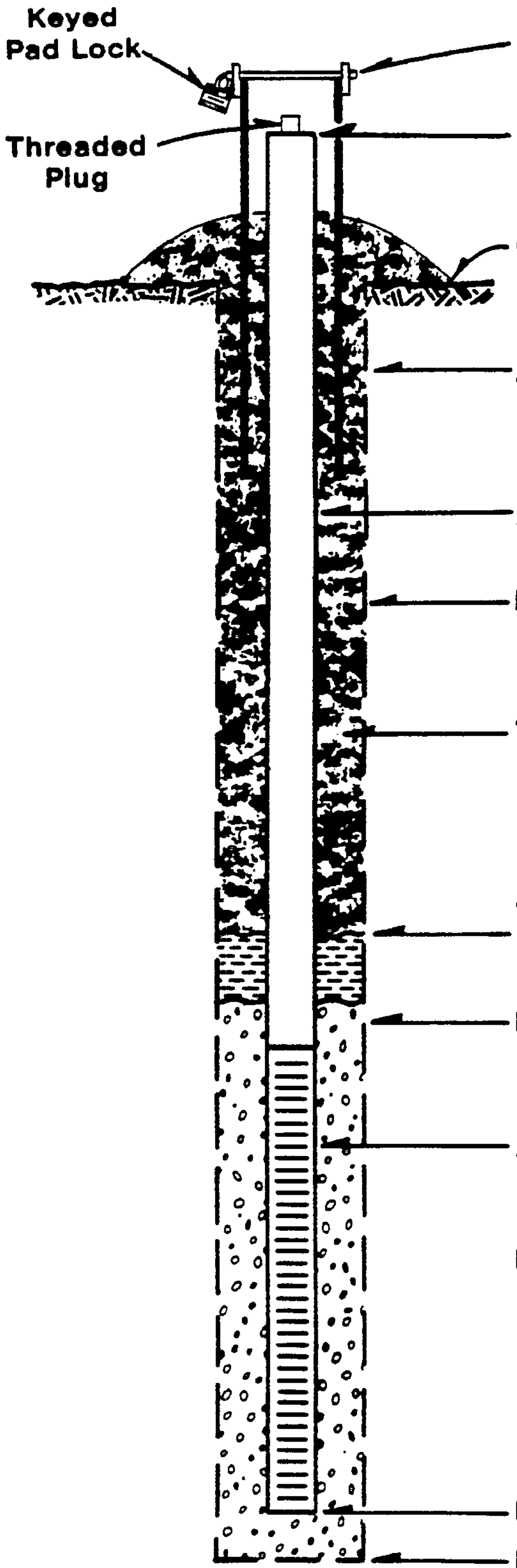
Depth of borehole 79.0 ft

Note: Centralizers set at 46.3 ft and 76.6 ft below ground surface

REPORT OF MONITORING WELL NO. MW-4B

DRAWN BY: DG	CHECKED BY: J.B.	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO:

AR301070



Elevation of top of surface casing: 15.02 ft

Elevation of top of riser pipe: 14.76 ft

Ground Elevation: 12.36 ft

I.D. of surface casing: 0.50 ft

Type of surface casing: steel
5 ft total length

I.D. of riser pipe: 0.33 ft

Type of riser pipe: flush threaded SCH 40 PVC

Diameter of borehole: 0.67 ft

Type of backfill: Cement/Bentonite Grout

Type of seal: Bentonite Pellets

Depth to top of seal: 94.0 ft

Depth to top of sand pack: 105.0 ft

Depth to top of screen: 110.0 ft

Type of screened section: 0.020 inch
wire wrapped stainless steel

I.D. of screened section: 0.33 ft

Depth to bottom of well: 120.0 ft

Depth of borehole: 132.0 ft

Note: Centralizers set at 60 ft and 100 ft below ground surface

REPORT OF MONITORING WELL NO. MW-4C

DRAWN BY: D.G	CHECKED BY: J B	PROJECT NO: 87C2665-1B	DATE 8/27/87	FIGURE NO

AR301071

Elevation of top of surface casing 5.82 ft

Elevation of top of riser pipe 5.58 ft

Ground Elevation 2.75 ft

I.D. of surface casing 0.50 ft
Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft
Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets
Depth to top of seal 2.5 ft

Depth to top of sand pack 3.5 ft

Depth to top of screen 2.7 ft
Type of screened section 0.010 inch
slotted SCH 40 PVC

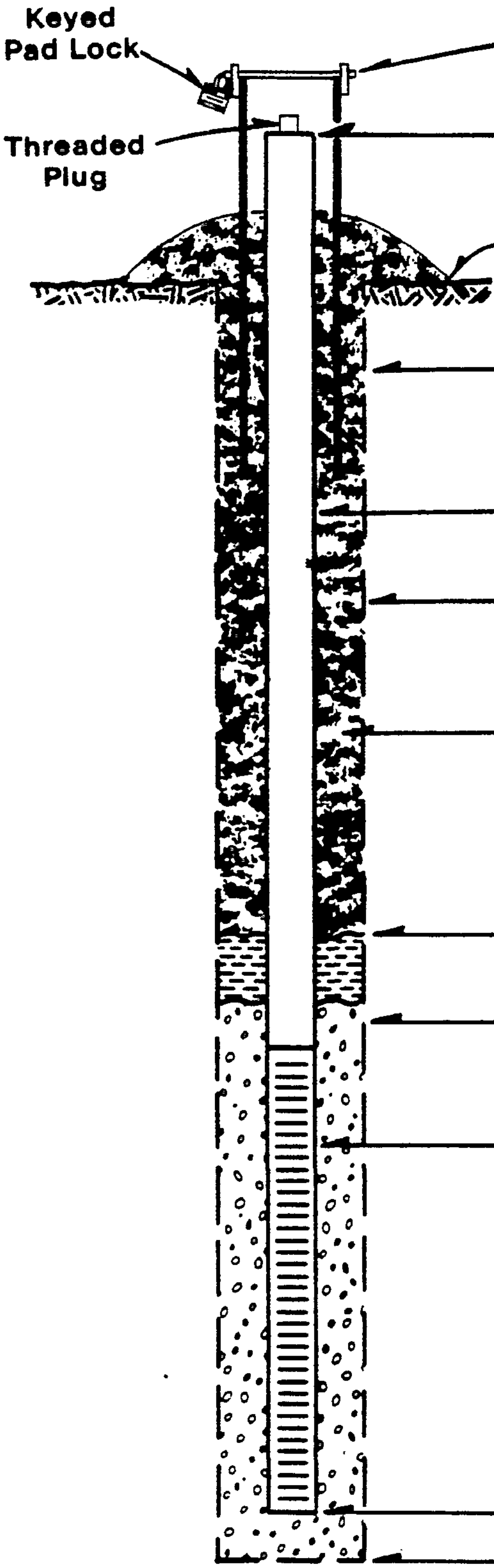
I.D. of screened section 0.33 ft

Depth to bottom of well 12.7 ft
Depth of borehole 12.7 ft

REPORT OF MONITORING WELL NO. MW-5A

DRAWN BY: DG	CHECKED BY: J.B.	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO.

AR301072



Elevation of top of surface casing 5.24 ft

Elevation of top of riser pipe 4.98 ft

Ground Elevation 2.17 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel

5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets

Depth to top of seal 65.6 ft

Depth to top of sand pack 73.6 ft

Depth to top of screen 76.0 ft

Type of screened section 0.020 inch wire wrapped stainless steel

I.D. of screened section 0.33 ft

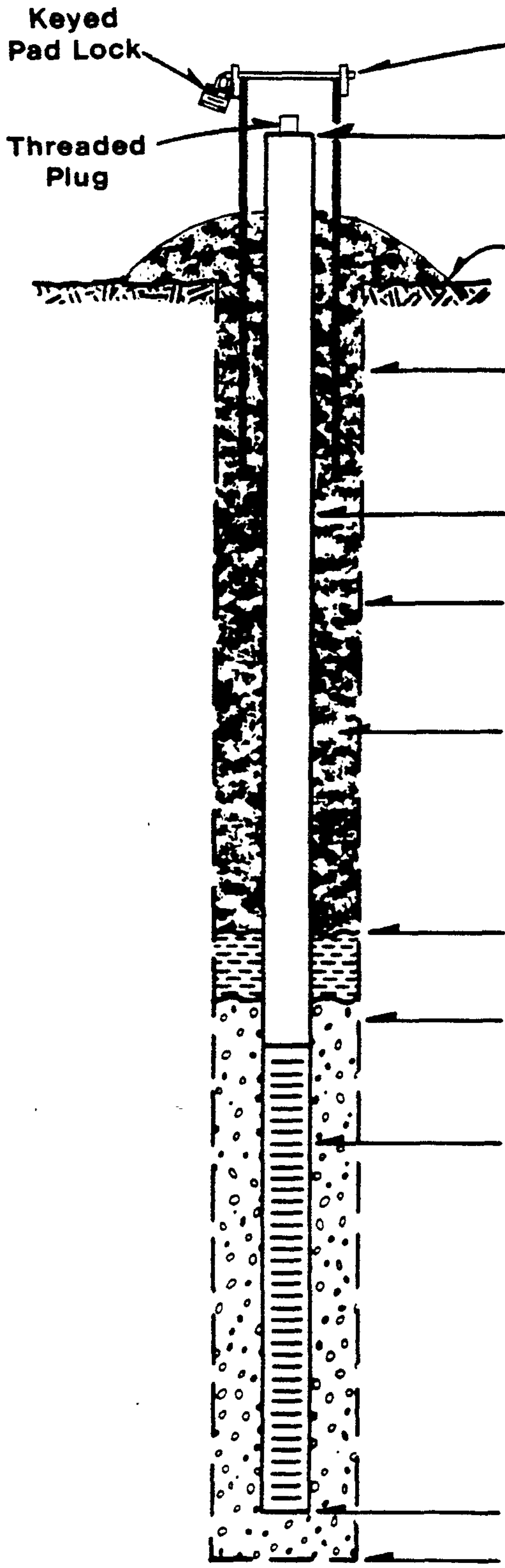
Depth to bottom of well 90.6 ft

Depth of borehole 93.0 ft

Note: Centralizer set at 25 ft below ground surface

REPORT OF MONITORING WELL NO. MW-5B

DRAWN BY:	CHECKED BY:	PROJECT NO:	DATE:	FIGURE NO
D G	J B	87C2665-1B	8/27/87	



Elevation of top of surface casing 5.34 ft

Elevation of top of riser pipe 5.13 ft

Ground Elevation 2.38 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel

5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets

Depth to top of seal 108.0 ft

Depth to top of sand pack 111.0 ft

Depth to top of screen 113.5 ft

Type of screened section 0.020 inch

wire wrapped stainless steel

I.D. of screened section 0.33 ft

Depth to bottom of well 124.9 ft

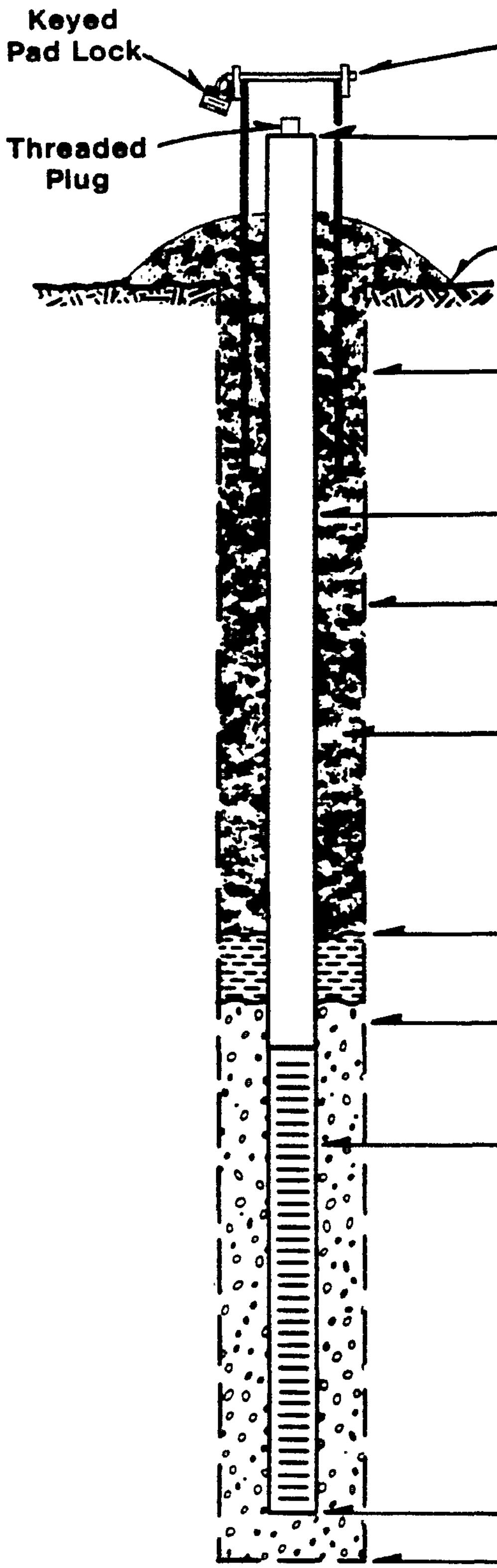
Depth of borehole 162.0 ft

Note: Centralizers set at 55 ft and 105 ft below ground surface

REPORT OF MONITORING WELL NO. MW-5C

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO.

AR301074



Elevation of top of surface casing 7.71 ft

Elevation of top of riser pipe 7.33 ft

Ground Elevation 4.39 ft

I.D. of surface casing 0.5 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Bentonite Pellet

Type of seal Bentonite Pellet

Depth to top of seal 1.0 ft

Depth to top of sand pack 3.5 ft

Depth to top of screen 5.0 ft

Type of screened section 0.010 inch
slotted SCH 40 PVC

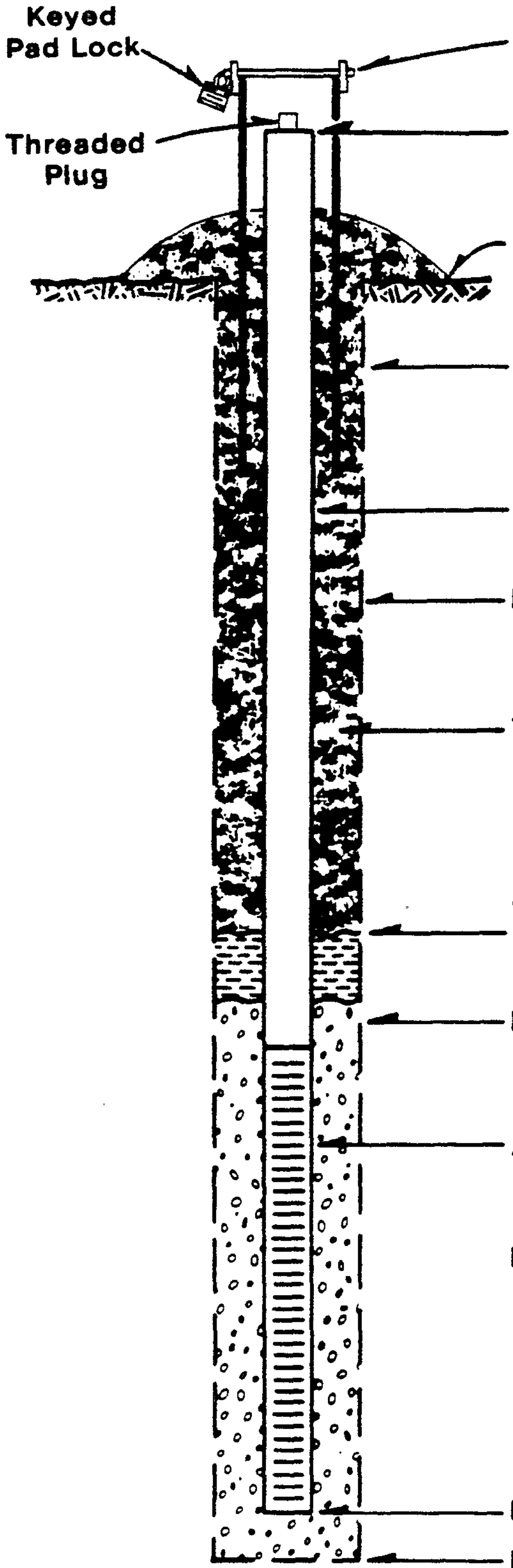
I.D. of screened section 0.33 ft

Depth to bottom of well 24.7 ft

Depth of borehole 30.0 ft

REPORT OF MONITORING WELL NO. MW-6A

DRAWN BY: D.G	CHECKED BY: J.B	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO.



Elevation of top of surface casing 7.77 ft

Elevation of top of riser pipe 7.48 ft

Ground Elevation 5.11 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel 5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Slurry

Depth to top of seal 60.0 ft

Depth to top of sand pack 63.8 ft

Depth to top of screen 65.0 ft

Type of screened section 0.020 inch wire wrapped stainless steel

I.D. of screened section 0.33 ft

Depth to bottom of well 77.0 ft

Depth of borehole 80.0 ft

Note: Centralizers set at 15.0 ft and 60.9 ft below land surface

REPORT OF MONITORING WELL NO. MW-6B

DRAWN BY: D.G	CHECKED BY: J.B	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO:

Elevation of top of surface casing 7.67 ft

Elevation of top of riser pipe 7.38 ft

Ground Elevation 4.70 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel

5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.67 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets

Depth to top of seal 88.3 ft

Depth to top of sand pack 94.8 ft

Depth to top of screen 100.5 ft

Type of screened section 0.010 inch

slotted SCH 40 PVC

I.D. of screened section 0.33 ft

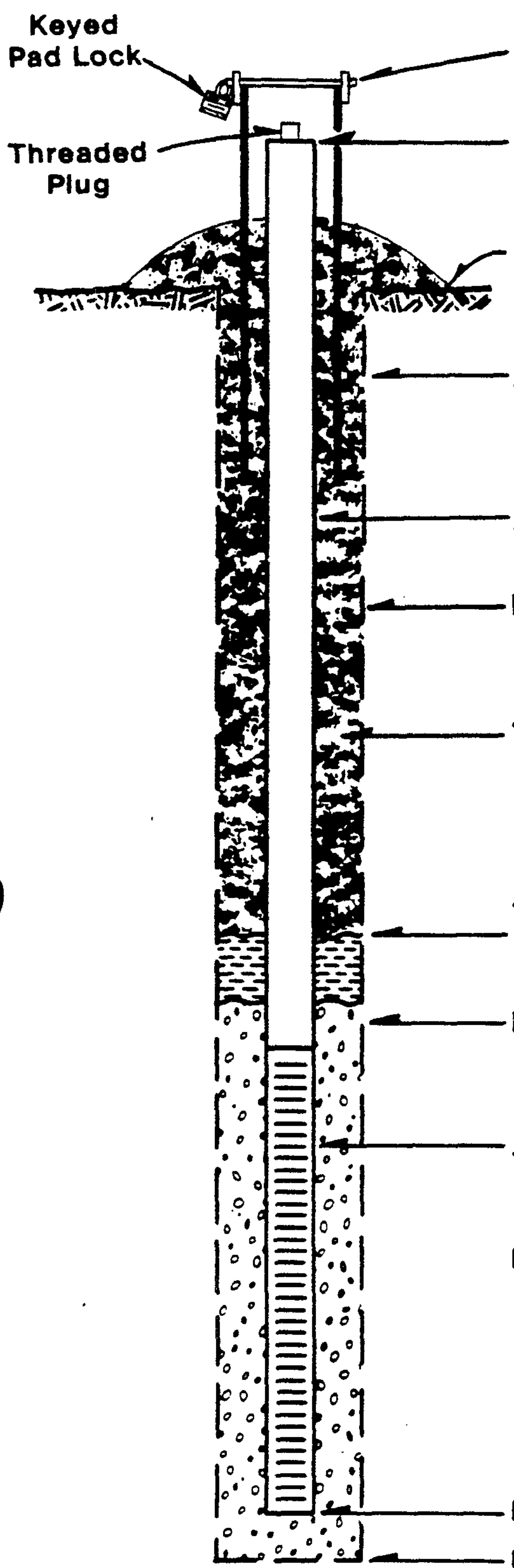
Depth to bottom of well 110.5 ft

Depth of borehole 152.0 ft

Note: Cement/Bentonite grout from 152 ft to 118 ft

REPORT OF MONITORING WELL NO. MW-6C

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO



Elevation of top of surface casing 8.33 ft

Elevation of top of riser pipe 7.96 ft

Ground Elevation 5.14 ft

I.D. of surface casing 0.50 ft
Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft
Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Bentonite Pellets

Type of seal Bentonite Pellets
Depth to top of seal 0.5 ft

Depth to top of sand pack 4.0 ft

Depth to top of screen 5.0 ft
Type of screened section 0.010 inch
slotted SCH 40 PVC

I.D. of screened section 0.33 ft

Depth to bottom of well 15.1 ft
Depth of borehole 16.0 ft

REPORT OF MONITORING WELL NO. MW-7A

DRAWN BY: D G	CHECKED BY: J.B	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO:

Elevation of top of surface casing 8.12 ft

Elevation of top of riser pipe 7.83 ft

Ground Elevation 5.17 ft

I.D. of surface casing 0.50 ft

Type of surface casing steel

5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Slurry

Depth to top of seal 52.0 ft

Depth to top of sand pack 60.0 ft

Depth to top of screen 63.0 ft

Type of screened section 0.020 inch wire wrapped stainless steel

I.D. of screened section 0.33 ft

Depth to bottom of well 78.5 ft

Depth of borehole 117.0 ft

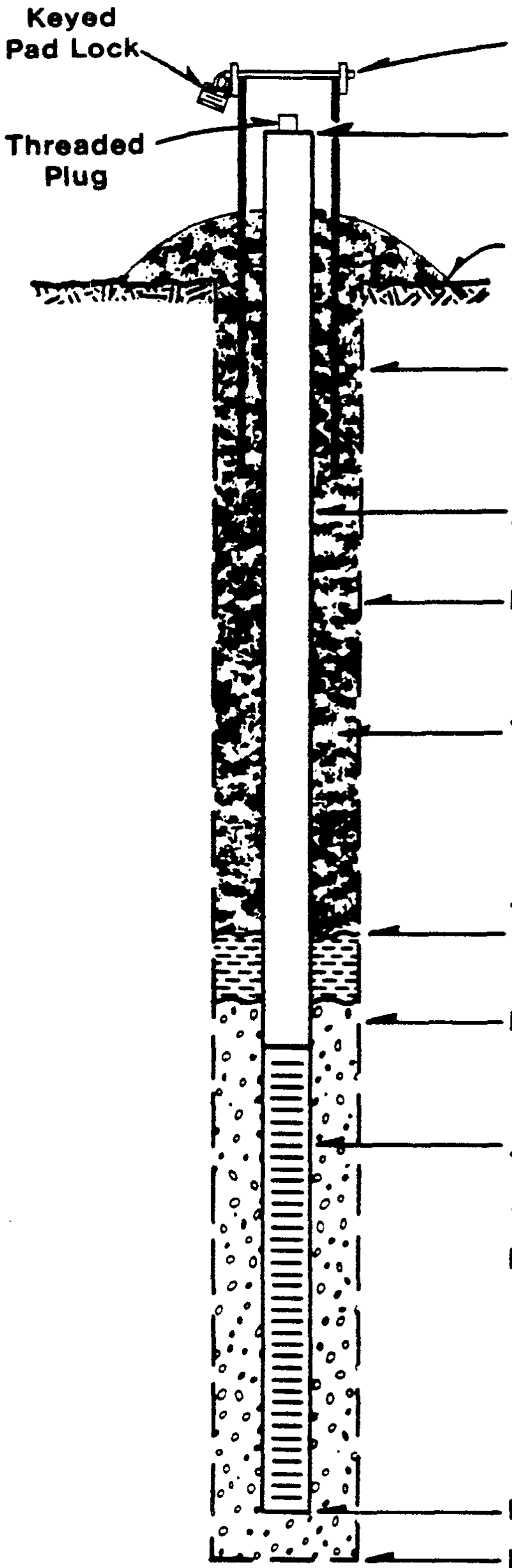
Note: Centralizers set at 33 ft and 53 ft below ground surface

REPORT OF MONITORING WELL NO. MW-7B

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO

AR301079

Woodward-Clyde Consultants



Elevation of top of surface casing 6.97 ft

Elevation of top of riser pipe 6.68 ft

Ground Elevation 4.11 ft

I.D. of surface casing 0.5 ft

Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft

Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.67 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite Pellets

Depth to top of seal 81.5 ft

Depth to top of sand pack 92.0 ft

Depth to top of screen 94.0 ft

Type of screened section 0.020 inch
wire wrapped stainless steel

I.D. of screened section 0.33 ft

Depth to bottom of well 109.0 ft

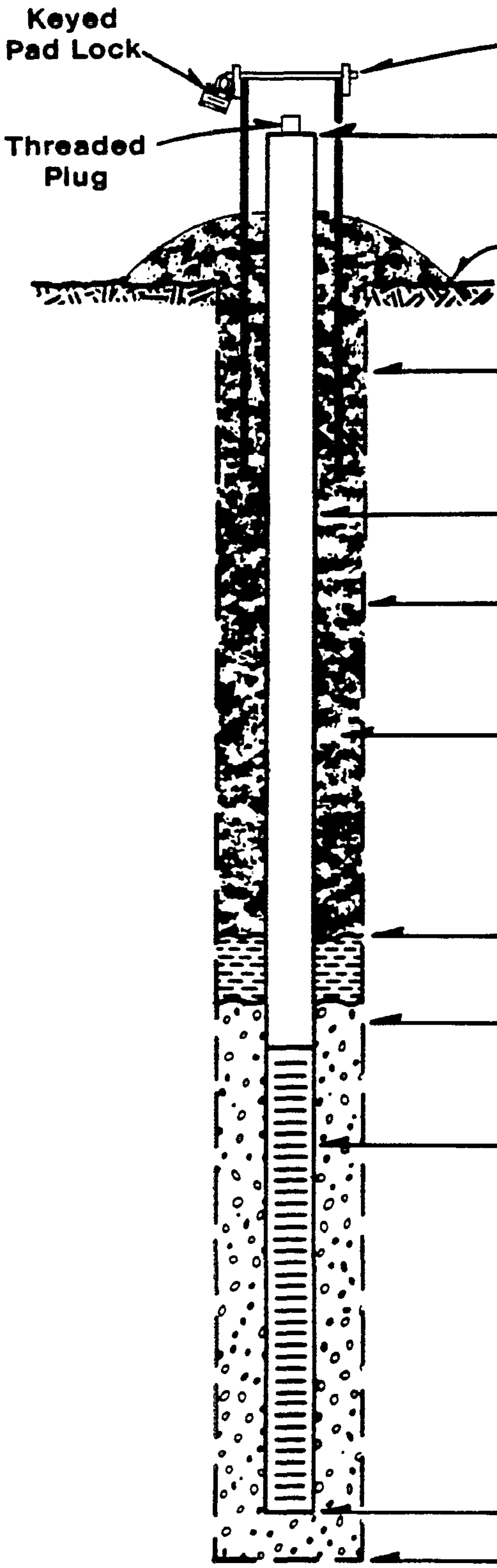
Depth of borehole 116.5 ft

Note: Centralizers set at 59 ft and 84 ft below ground surface

REPORT OF MONITORING WELL NO. MW-7C

DRAWN BY. D G	CHECKED BY J B	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO:

AR301080



Elevation of top of surface casing	7.36 ft
Elevation of top of riser pipe	7.10 ft
Ground Elevation	4.80 ft
I.D. of surface casing	0.50 ft
Type of surface casing	steel 5 ft total length
I.D. of riser pipe	0.33 ft
Type of riser pipe	flush threaded SCH 40 PVC
Diameter of borehole	0.83 ft
Type of backfill	Cement/Bentonite Grout
Type of seal	Bentonite Pellets
Depth to top of seal	1.5 ft
Depth to top of sand pack	2.0 ft
Depth to top of screen	2.0 ft
Type of screened section	0.010 inch slotted SCH 40 PVC
I.D. of screened section	0.33 ft
Depth to bottom of well	26.5 ft
Depth of borehole	29.5 ft

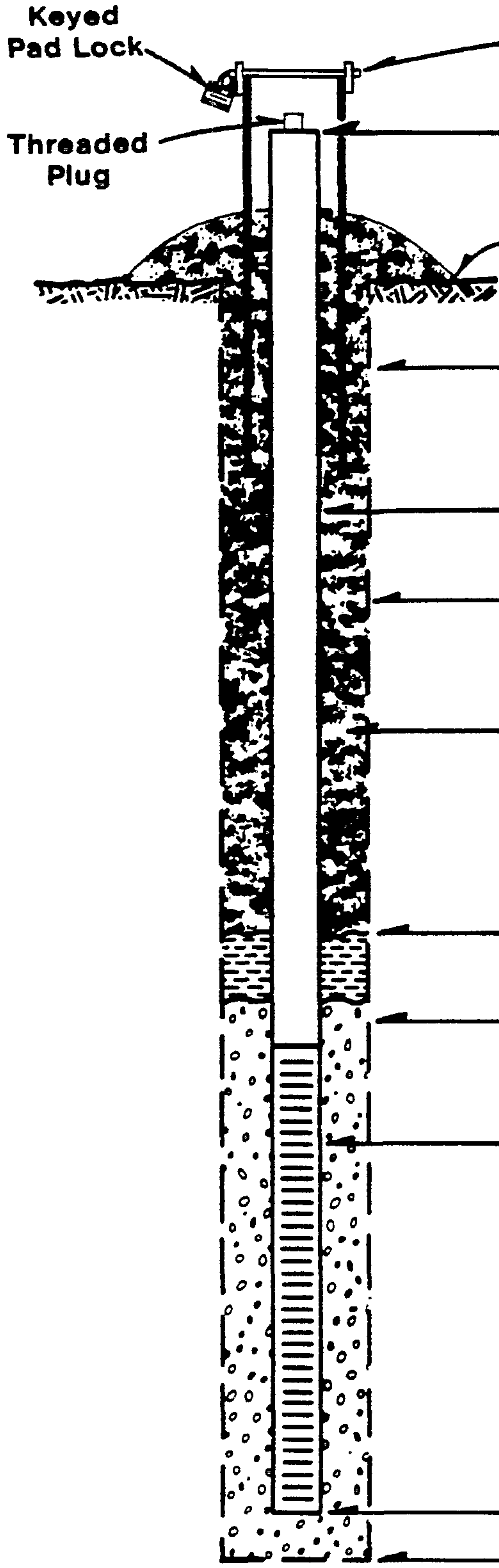
REPORT OF MONITORING WELL NO. MW-8

DRAWN BY:	CHECKED BY:	PROJECT NO:	DATE:	FIGURE NO
D G	J B	87C2665-1B	8/27/87	

- **Elevation of top of surface casing** 12.12 ft
- **Elevation of top of riser pipe** 11.78 ft
- **Ground Elevation** 9.21 ft
- **I.D. of surface casing** 0.50 ft
- **Type of surface casing** steel
  5 ft total length
- **I.D. of riser pipe** 0.33 ft
- **Type of riser pipe** flush threaded SCH 40 PVC
- **Diameter of borehole** 0.83 ft
- **Type of backfill** Bentonite Pellets
- **Type of seal** Bentonite Pellets
- **Depth to top of seal** 0.5 ft
- **Depth to top of sand pack** 3.6 ft
- **Depth to top of screen** 5.0 ft
- **Type of screened section** flush
  0.010 inch slotted PVC
- **I.D. of screened section** 0.33 ft
- **Depth to bottom of well** 24.7 ft
- **Depth of borehole** 30.0 ft

REPORT OF MONITORING WELL NO. MW-9

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO



Elevation of top of surface casing 9.10 ft

Elevation of top of riser pipe 8.75 ft

Ground Elevation 6.34 ft

I.D. of surface casing 0.50 ft
Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft
Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Cement/Bentonite Grout

Type of seal Bentonite
Depth to top of seal 1.5 ft

Depth to top of sand pack 3.0 ft

Depth to top of screen 4.0 ft
Type of screened section 0.010 inch
slotted SCH 40 PVC

I.D. of screened section 0.33 ft

Depth to bottom of well 24.8 ft
Depth of borehole 25.0 ft

REPORT OF MONITORING WELL NO. MW-11

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO

AR301083

Elevation of top of surface casing: 6.85 ft

Elevation of top of riser pipe: 6.49 ft

Ground Elevation: 4.10 ft

I.D. of surface casing: ______

Type of surface casing: steel
5 ft total length

I.D. of riser pipe: 0.33 ft

Type of riser pipe: flush threaded SCH 40 PVC

Diameter of borehole: 0.83 ft

Type of backfill: Cement/Bentonite Grout

Type of seal: Bentonite Pellets

Depth to top of seal: 1.5 ft

Depth to top of sand pack: 3.0 ft

Depth to top of screen: 5.3 ft

Type of screened section: 0.010 inch
slotted SCH 40 PVC

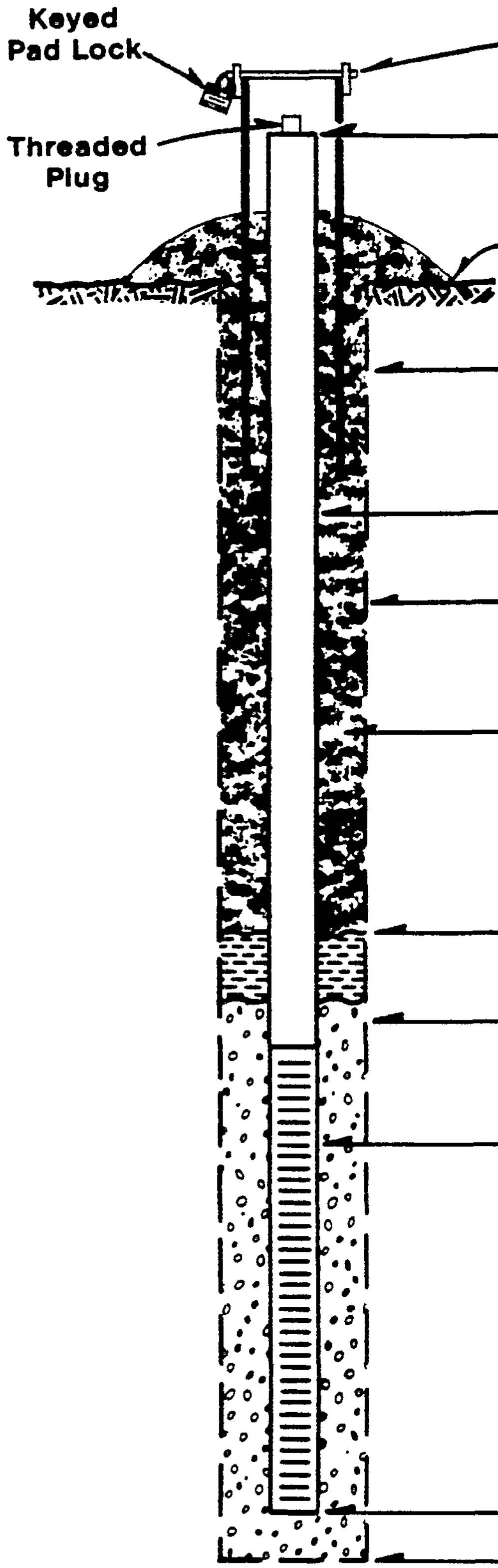
I.D. of screened section: 0.33 ft

Depth to bottom of well: 25.3 ft

Depth of borehole: 25.6 ft

REPORT OF MONITORING WELL NO. MW-13

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO:



Elevation of top of surface casing: 10.84 ft

Elevation of top of riser pipe: 10.52 ft

Ground Elevation: 7.69 ft

I.D. of surface casing: 0.50 ft

Type of surface casing: steel
5 ft total length

I.D. of riser pipe: 0.33 ft

Type of riser pipe: flush threaded SCH 40 PVC

Diameter of borehole: 0.83 ft

Type of backfill: Bentonite Pellets

Type of seal: Bentonite Pellets

Depth to top of seal: 0.5 ft

Depth to top of sand pack: 4.0 ft

Depth to top of screen: 5.0 ft

Type of screened section: 0.010 inch
slotted SCH 40 PVC

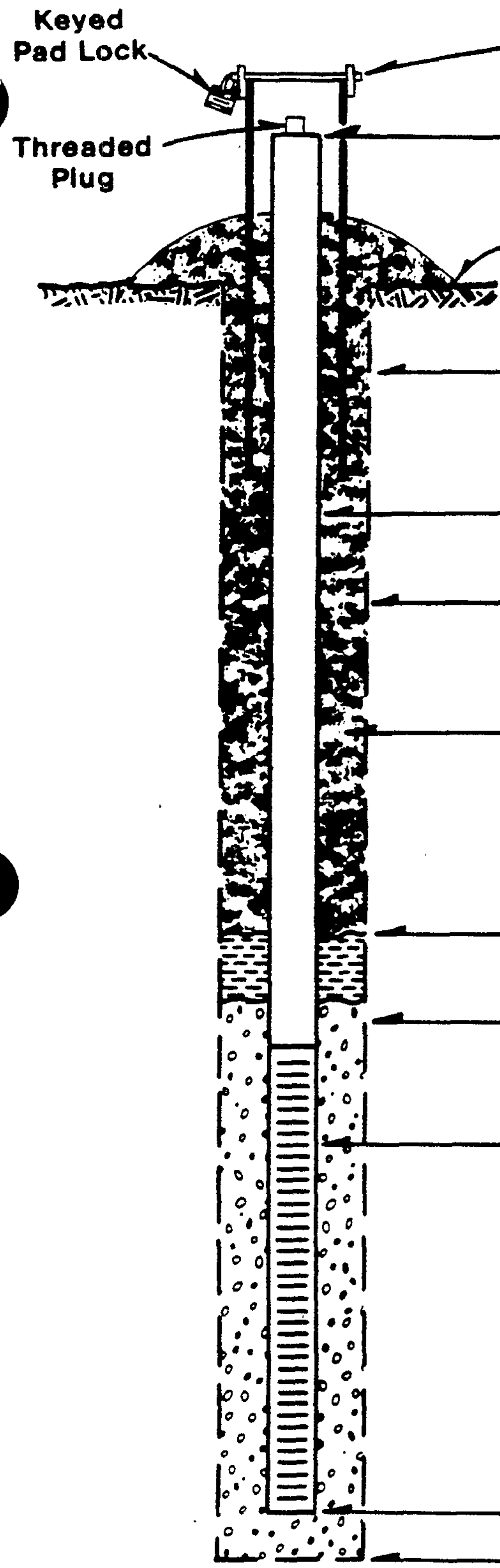
I.D. of screened section: 0.33 ft

Depth to bottom of well: 24.4 ft

Depth of borehole: 30.0 ft

REPORT OF MONITORING WELL NO. MW-14

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO



Elevation of top of surface casing 13.50 ft

Elevation of top of riser pipe 13.16 ft

Ground Elevation 10.73 ft

I.D. of surface casing 0.50 ft
Type of surface casing steel
5 ft total length

I.D. of riser pipe 0.33 ft
Type of riser pipe flush threaded SCH 40 PVC

Diameter of borehole 0.83 ft

Type of backfill Bentonite Pellets

Type of seal Bentonite Pellets
Depth to top of seal 1.0 ft

Depth to top of sand pack 4.0 ft

Depth to top of screen 5.0 ft
Type of screened section 0.010 inch
slotted SCH 40 PVC

I.D. of screened section 0.33 ft

Depth to bottom of well 15.1 ft
Depth of borehole 17.0 ft

REPORT OF MONITORING WELL NO. MW-15

DRAWN BY: DG	CHECKED BY: JB	PROJECT NO: 87C2665-1B	DATE: 8/27/87	FIGURE NO

Appendix B

Hydrogeology Report
DuPont Newport Site
Newport, Delaware

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LIST OF FIGURES
(Continued)

1.0 DATA OBJECTIVES

The primary objectives of this investigation were to review the data relevant to groundwater flow in the vicinity of the Newport site and to estimate groundwater flow directions. The data reviewed in preparing this report included the regional setting, boring and well installation, site stratigraphy, downhole geophysics, aquifer tests and groundwater head data collected for this investigation. The supporting task reports which include these data are provided as Appendices A, C, and D within this Work Plan and can be referred to for more complete discussion of methodology and data interpretation. In addition, water level data are provided in Appendix E, covering the monitoring periods before, during, and after the aquifer tests.

1.1 BASIS FOR INVESTIGATION

The Du Pont Newport site in Newport, Delaware was proposed by EPA to be included in the National Priority List (NPL). Groundwater receptors identified by EPA included private wells located about one mile south of the Newport site and a public water supply well within three miles of the Newport site. A hydrologic connection between the Newport site and the potential receptors was presumed ("Evaluation of Existing Conditions at the Newport Plant - North Disposal Site", WCC, March, 1987; "Proposed Work Plan - Remedial Investigation/Feasibility Study, Newport Plant - North Disposal Site, Newport, Delaware", WCC, August, 1987).

Woodward-Clyde Consultants (WCC) reviewed the EPA analysis and conducted a detailed review of existing data (published or otherwise) that were relevant to the hydrogeology at the Newport site. The existing data indicated that the Christina River located south of the North Disposal site was probably a hydrologic boundary (discharge zone) to the shallow groundwater system, which was in agreement with the conclusions reached by the Delaware Geological Survey on the basis of regional hydrologic analyses (Petty, et al., 1983, Woodruff, 1984). The Christina River valley was mapped by Petty et al. (1983) and Woodruff (1985) as a zone of groundwater discharge. Site-specific, conclusive data to support this conclusion, however, were not available.

Thus Du Pont directed WCC to conduct a full scale site investigation at the Newport site beginning in June, 1987 to characterize specific details of the Site's hydrogeology.

2.0 HYDROSTRATIGRAPHY

2.1 REGIONAL SETTING

The Newport site is located within the Atlantic Coastal Plain Province, proximal to the Appalachian Piedmont Province (Figure 1). The Coastal Plain is a relatively flat and low area with elevations not exceeding 100 feet above mean sea level. The area adjacent to the Delaware Bay is exposed to tidal flooding and is characterized by conspicuous marshes and estuaries. Most of the streams in this zone, including the Christina River, are tidal or have at least a tidal segment. Stream valleys are shallow compared with those of the Piedmont Province to the north.

The Piedmont Province is an area of diversified relief dissected by narrow a deep stream valleys with residual high areas rising above the general upland level. It is composed of folded Paleozoic and Precambrian metamorphic and igneous rocks consisting predominantly of banded gneiss and schist. The surface of these crystalline rocks of the Piedmont slopes southward and southeastward forming the basement upon which lies the wedge-shaped mass of sedimentary rocks of the Coastal Plain.

The Piedmont and Coastal Plain Provinces are separated by the Fall Zone (see Figure 1), which divides the area of predominant erosion (Piedmont Province) from the area of predominant deposition (Coastal Plain Province). The Piedmont streams are characterized by relatively steep gradients and, therefore, most of their sediment load is transported out into the Coastal Plain and only a minor part is deposited in their channels and flood plains. The gradients of the Coastal Plain streams draining into Delaware Bay, however, are very gentle and a large part of their sediment load is deposited before reaching the bay. The process of deposition is particularly effective in the tidal marsh area along the bay or its tributaries.

2.1.1 REGIONAL STRATIGRAPHY

The wedge-shaped mass of sedimentary deposits comprising the Coastal Plain in the Newport area consists of the Pleistocene Columbia Formation and the Cretaceous Potomac Formation.

Columbia Formation - The Pleistocene (Quaternary) sediments of the Columbia Formation were deposited on the eroded surface of the underlying Potomac Formation sediments in the area. The formation includes gravelly coarse and medium sands with some interbedded silts and clays. The sands are moderately to poorly sorted, cross-bedded, yellow to brownish-yellow in color, and contain on the average about 5 percent clay and silty matrix. Fine sediments are abundant locally and gravels are subordinate. The Columbia sediments were deposited in stream channels, flood plains, and associated environments.

In northern New Castle County, the Columbia Formation is generally thin, having an average thickness of about 30 feet, except in paleochannels where the maximum known thickness is about 105 feet. The Columbia thickens to the south and reaches a maximum thickness in excess of 150 feet. In the Newport area, the reported thickness range of Columbia sediments is 0 to in excess of 20 feet (Woodruff and Thompson, 1975).

Potomac Formation - The Potomac Formation consists of a southeastward thickening wedge of sand, silt, and clay beds that were deposited on crystalline bedrock by ancient streams as floodplain, channel, bar deposits, and, perhaps, by alluvial fans (Figure 2). The Formation and its stratigraphic equivalents extend from Long Island southward to the mid-Atlantic States. Within the area of interest, the Potomac sediments comprise more than 50 percent of the total sequence of the Coastal Plain sediments. The geometry of the sand bodies is characterized by shoestring form, are discontinuous and, thus, individual sand beds are difficult to correlate laterally. The Potomac Formation thickens to the southeast and sandy units tend to occur in the lower half of the Formation.

The Potomac Formation typically is divided into an upper and lower sandy unit, separated by a clay and silt unit. The thickness of the upper sandy unit may include thin interbedded clays or silts and is measured from the first Potomac Formation sand lying beneath the Columbia Formation downward to the top of a mappable clay. Well sorted, fine to medium sands generally make up the sandy section of the upper part of the Formation, but sands may locally be coarse in channels. The upper sandy unit is in direct contact with the overlying sediments of the Columbia Formation from the Greater Wilmington Airport area northward toward the Christina River (Figure 2), but the unit apparently does not extend beneath the Christina River (Woodruff, 1985). The clay underlying the upper sandy interval occupies about the middle one-third of the Potomac Formation and hydrologically separates the upper sands from the lower sandy unit (Woodruff, 1985).

By comparison, the lower sandy zone of the Potomac Formation extends farther north than the upper sandy zone and underlies Columbia sediments in the entire area surrounding the Newport Site until it pinches out farther to the north. The lower part of the Potomac Formation is typically described as variegated red, gray, purple, yellow, and white, frequently lignitic, silt and clays containing interbedded white, gray, and rust-brown co sands and some gravel (Woodruff and Thompson, 1975). The relative positions of these various stratigraphic units are shown schematically in Figure 2.

2.1.2 REGIONAL HYDROGEOLOGY

Potomac sand units of the Potomac Formation or its correlatives are important aquifers throughout the Eastern United States. In Delaware, the upper and lower sand units of Potomac Formation provide significant quantities of potable water. Locally, the surficial Columbia Formation provides potable water, particularly to non-community systems and single users. Within the Newport area, Petty et al. (1983) and Woodruff (1981, 1984, 1985) reviewed geologic, structural, and hydrologic data. Their reports relied, in part, on previous reports of groundwater hydrogeology (Johnston, 1973; Martin and Denver, 1982). The regional hydrogeology of this area as prescribed in these reports is synthesized briefly in the following paragraphs.

As a surficial, unconfined aquifer the Columbia Formation is recharged by infiltration from precipitation, and where it is relatively thick or it contains sand or gravel units it can be an important aquifer. Within the vicinity of the Newport Site some residential and commercial users of groundwater from the Columbia Formation have been identified along Old Airport Road, starting adjacent to the southwest corner of the Newport site property boundary. In addition, as a hydrologic unit, the Columbia Formation serves to recharge lower aquifers by vertical discharge, and this may be true in areas where the Columbia is in contact with sand units of the upper Potomac Formation and where the vertical gradients are downward. In areas where vertical gradient from the underlying Potomac Formation to the Columbia Formation is upward, no such recharge would be anticipated.

The sand members of the Potomac Formation are the major aquifers in the Coastal Plain of Delaware except where saline water is encountered. The sand members are separated from each other by the middle clays and silts which act to retard vertical leakage from one member to another. Recharge of the upper sand units in the Potomac Formation are by vertical leakage from the overlying Columbia Formation (Figure 2). The upper sand member of the Potomac Formation was not encountered at the Newport site and is considered to pinch out a few miles southeast of the Site. The lower Potomac sand member is recharged near its outcrop area east of the Fall Zone (Figure 2) and by vertical leakage through the overlying clay beds when the vertical gradients are downward and allow for recharge. Regional hydrologic analyses by Woodruff (1985) and Petty et al. (1983) show that the valley of the Christina River at Newport is an area of groundwater discharge or upward flow from the lower Potomac Formation into the river and marshy areas of the Christina River valley. Groundwater from the Columbia Formation would not be expected to infiltrate into the Potomac Formation aquifer in an area of groundwater discharge.

2.2 SITE HYDROSTRATIGRAPHY

2.2.1 SITE SETTING

Both the North and South Disposal sites (see Figure 3) are adjacent to the banks of the Christina River. Except for the fill areas, the river bank areas are tidal marsh.

The Christina River at this location demonstrated a tidal range of about 5 feet when its ranges were monitored for this program in July - August, 1987.

2.2.2 HYDROSTRATIGRAPHY

Seven test borings were drilled by WCC during June and July, 1987 (Figure 4). The borings were logged by WCC geologists based on soil samples collected at five foot centers in advance of the boring (Appendix A). In addition, each borehole was logged upon completion using geophysical methods (Appendix C). These logs (Appendix A) were used, along with visual examination of the soil samples, to define five hydrostatigraphic units (Table 1). Although the units appear in all boreholes examined, the units frequently vary markedly in color and lithology. The lithology varies from thin bedded kaolinitic clays, to clayey silts, fine to coarse sands, gravels and cobbles. All of the sediments contain clay and only a few zones of limited thickness (usually less than 15 feet) appear to yield much water.

Due to the similarity of the lithologic sequences overlying the bedrock at the Site, the division of sediments into hydrostratigraphic units was subjective. The units were grouped according to stratigraphic characteristics and then were compared to downhole geophysical logs for confirmation. (Refer to Appendices A and C for a more detailed analysis.)

The hydrostratigraphic units identified in the study area differ in clay content and appear to define water-bearing units and semi-confining units (aquitards). These units are correlatable across the Site and appear to be correlatable to the regional stratigraphy discussed in Section 2.1 (refer to Figure 2). Unit I (Shallow Zone) is correlated with the Columbia Formation. Unit II (Semi-confining Unit) probably is equivalent to the silty clay unit discussed by Woodruff (1985) that separates the upper sand member from the lower sand member; the upper sand member is not present at the Site. Units III_A (Intermediate Zone), III_B, and IV (Deep Zone) are correlated with the lower Potomac Formation clayey sands (Figure 2). In summary, water-bearing units at the Site include Unit I (= Columbia Formation), Unit III_A (= part of the lower Potomac Formation sand member), and Unit IV (= part of the lower Potomac Formation sand member), as discussed by Woodruff (1985); the confining beds (aquitards) include Unit II (= part of the middle Potomac Formation clays and silts) and

Unit III_B (= silty part of the lower Potomac Formation sand member) and Unit V (= decomposed bedrock).

Two topographic profiles and geologic cross-sections to facilitate stratigraphic interpretation and hydrologic analysis are presented in Figures 5 and 6. The cross-sections are shown as straight line and data from nearby borings and wells were projected into the profiles. Consequently, the topography along the cross-sections does not coincide with the top of well elevations at some well locations. The screened intervals of all of the previously existing active wells (Table 2) and the WCC installed wells (Appendix A) are shown on the two cross-sections. Cross-section A-A' was drawn south of the North Disposal site and extends southeastward, approximately in the dip direction, through MW-6B to Old Airport Road (Figure 4). The section extends through part of the extensive auto salvage yards located south of the Christina River, west of the Du Pont property, and northwestward of Old Airport Road. Cross-Section B-B' extends from the MW-1 cluster to the MW-7 cluster through the North and South Disposal sites. The units are similar in character and thickness to those shown in cross-section A-A'. The data suggest that the units, as defined, are continuous over the entire Site, and, although somewhat variable, can be considered as distinct hydrologic units.

Unit I (Columbia Formation) has been identified everywhere on the Site, both north and south of the Christina River. The base of the Columbia Formation extends across the Site and beneath the Christina River, which is about 12 feet deep in the area of the Site. It is variable and contains discontinuous sand beds that together serve as an upper water-bearing unit (Shallow Zone). Unit II, which is more than 20 feet throughout the Site, contains a dominant clay bed section that exceeds 15 feet thickness throughout the Site, and separates the upper water-bearing Columbia Formation Unit (I) from the Intermediate Zone (Unit III_A), which belongs to the lower Potomac Formation. The Deep Zone (Unit IV) is separated from Unit III_A by a 20 to 30 foot layer (Unit III_B) that contains clay but is more sandy than the upper confining unit (II).

3.0 HYDROGEOLOGY

Regional analysis of groundwater flow in the Newport area (Petty, et al., 1983; Woodruff, 1984) has been reported in the literature. These studies have concluded that the

Christina River valley in the vicinity of Newport is a groundwater discharge area whereby flow from the lower Potomac aquifer discharges through the Columbia Formation to the Christina River. The investigation conducted by WCC at the Newport site confirmed the publishec hydrogeologic interpretations.

Data from 27 groundwater monitoring wells installed by WCC at the Site (Appendix A), with 12 pre-existing wells (Table 2) were used for hydrogeologic analyses. As part of the investigation, WCC conducted two aquifer tests (Appendix D), one each north and south of the Christina River for data analysis. Static water levels at 31 wells and tide elevations were collected continuously (15 minute intervals) for at least 24 hours prior to the start-up of each test. In the period of August 1 through 8, all wells (except MW-11, MW-6A, MW-6B, MW-6C and MW-13, which are located at the southern border of the Site, and wells DM-8, SM-5, and WW-11 located on the Ciba-Giegy plant) were monitored (Appendix E).

Static water elevations were collected manually at those wells not electronically monitored and were incorporated into the hydrogeologic analyses for this period. Because it was apparent that many of the wells respond to tidal fluctuations of the Christina River (see hydrographs in Appendix E), hydrogeologic analysis is presented for the range of tides that was observed on August 4, 1987. The purpose was to assess the sensitivity of groundwater flow at the Site to river stage.

The well hydrographs (Appendix E) indicate that wells screened in the Intermediate and Deep Zones respond to a greater extent and at a greater distance from the Christina River than wells completed in the Shallow Zone. For example, a comparison of the hydrographs of well MW-4A with wells MW-4B or MW-4C demonstrates this phenomenon. The water level in the Shallow Zone at this location, although located about 100 feet from the river, does not respond measurably to tidal fluctuations, whereas the head in the wells in the Intermediate and Deep Zones responds to the semi-diurnal tide of the Christina River. Similarly, the response of two other Shallow Zone wells, MW-1 and MW-2, is immeasurable compared to the corresponding response of the associated intermediate and deeper zones. The failure of the Shallow Zone wells to respond to tidal ranges of 5 feet or more is attributed to the fact that the groundwater in the Shallow Zone (Unit I) occurs under water table (unconfined) conditions.

In order for a response to tidal fluctuations to occur under water table conditions, a mass of water must move to or away from the well as a direct result of tidal fluctuations, which apparently is not the case at any of the shallow wells. On the other hand, the response of head to confined conditions reflects a pressure change that requires a change only in the pressure head with little movement of water necessary. Accordingly, the response at the Intermediate and Deep Zones is that of confined or semi-confined aquifer conditions.

3.1 PIEZOMETRIC HEADS

Piezometric head maps of the Newport Site that include both the North and South Disposal sites, were prepared for the three water-bearing zones (Units I, III_A, and IV) both for river low and river high-tide conditions for August 4, 1987 (Figures 7 through 12). Contours for the shallow zone are typical for a water table aquifer in that they often mimic topography; that is, groundwater flows from areas of higher elevations to areas of lower elevations. The irregular contours shown are consistent with the topography of the ditches or low lying areas and with the elevation of the Christina River.

The contours of the Intermediate and Deep Zones, both for low and high tides, indicate piezometric surfaces that slope southeastward. The contour lines, however, are not evenly spaced across the Site. The gradients are four to ten times greater north of the southern shoreline of the Christina River than they are south of the Christina River. For example, the horizontal gradient of the Intermediate Zone (Unit III_A) at low tide from MW-2B to DM-4 located on the south side of the Christina River is about 0.01, whereas the horizontal gradient from DM-4 to MW-5B south of the river is about 0.001. This represents a ten-fold decrease in gradient. A similar reduction in gradient from steep to shallow is apparent in the Deep Zone (Unit IV). These marked changes in gradient indicate that the river acts as a hydraulic boundary.

To analyze the vertical flow further, hydraulic head contours in vertical sections were prepared along sections A-A' and B-B' for both low and high tide (Figures 13 to 16). Contours of the head data for the Shallow Zone were used to develop the water table shown in the profiles. Contours of heads for the Intermediate and Deep Zones along the profile lines were transferred to the tops of Units III_A and IV, respectively. Contours of potentiometric head in profile then were developed for each vertical section.

An analysis of the contours shown in Figures 13 to 16 indicates a strong upward gradient (0.1 or greater in some places), from the Intermediate Zone, north of the southern edge of the Christina River. Flow lines interpreted on the basis of these contours indicate that the potential for flow is from the Intermediate Zone through the semi-confining bed and upward through Unit I into the Christina River. Based on the piezometric head data, precipitation that infiltrates into the Columbia Formation (Unit I) north of Christina River at the Site, including the North Disposal site, would discharge to the Christina River. In addition, the Columbia Formation is recharged from the underlying Potomac Formation.

To estimate the extent of groundwater discharge to the surface in the vicinity of the North Disposal site potentiometric head difference maps (Figures 17 and 18), both for low and high tide, were constructed. These figures show the difference in head between the Intermediate and Shallow Zones. In areas where the heads of the Intermediate Zone are greater than that of the Shallow Zone, an upward potential exists and groundwater will discharge to the surface. The data are explicit and show the Christina River valley in the vicinity of the Newport site to be a groundwater discharge zone. No groundwater flow path from the surface of the Site north of the Christina River to the subsurface south of the Christina River has been identified.

3.2 AQUIFER TESTS

As part of the Newport Site investigation, aquifer tests were conducted on two of the new wells. The unit tested for the aquifer test was the Intermediate Zone (Unit III_A), the uppermost water-bearing zone in the Potomac Formation at the Site. The pumping wells were MW-3B and MW-6B (Figure 4). Heads in more than 25 observation wells were monitored electronically during the drawdown and recover portions of each of the tests. (See Appendix E for hydrographs and all water level data before, during, and after the pumping tests.)

Results of the aquifer tests are discussed below. The water-bearing unit tested was Unit III_A, which underlies the shallow surface water-bearing unit at the Site. Estimates of transmissivity of this unit range from 2000 to 7000 gpd/ft over the entire Site including the Du Pont property south of the Christina River. Estimates of the storage coefficient range from 2×10^{-4} to 4×10^{-4}. These estimates of transmissivity fall within a relatively narrow range, and they are consistent with the interpretation of the geophysical logs and the stratigraphy of the area. (Stratigraphically, the water-bearing units show fairly uniform thickness and similar lithological variations in each of the seven test borings.) The storage coefficients are consistent with the semi-confining nature of the Intermediate Zone.

The hydraulic conductivity or permeability (transmissivity divided by aquifer thickness) of the Intermediate Zone varies comparably with the transmissivity since the thickness of the zone is fairly uniform over most of the Site. Using a typical transmissivity of 3000 gpd/ft and a 30-foot water-bearing zone thickness generates a typical permeability for Unit III_A of 100 gpd/ft^2.

The data indicating relatively uniform stratigraphic thickness and transmissivity in the water-bearing units, when interpreted with the piezometric head data described in Section 3.1, reinforce the concept that the Christina River acts as a significant line of groundwater discharge, and that groundwater flows from the deeper water-bearing units upward through the shallow water-bearing units and into the Christina River.

If we assume that the groundwater flow is in accordance with the conditions governing the applications of the Darcy equation,

$$Q = kia, \text{ where}$$

Q = discharge,
k = hydraulic conductivity (permeability)
i = gradient, and
a = cross sectional area,

then the effect of about an order of magnitude reduction in gradient (Figures 9-12) south of the river becomes apparent. North of the river the value of Q (discharge) for a given cross sectional area is a function of the gradient and transmissivity. Because there has been no significant change in thickness of the water-bearing units identified or of the transmissivity over the area, then gradient becomes the variable of significance. If cross-sectional area and the hydraulic conductivity are held constant, a reduction in the gradient south of the river would thereby require a reduction in the discharge. Thus, for a given cross sectional area the difference in Q (discharge) between the north and south side of the river can only be accommodated, assuming relatively uniform values for k and a and a reduction in i (gradient), by a loss of water from Unit III_A upward to the Christina River equivalent to the difference in $Q_r - Q_s$ in the example given.

For example consider the discharge for a one foot width of Unit III_A from well SM-3 to well DM-4 (Figure 11) at the river at low tide;

$Q_r = (3000/32) \times (6/420) \times (1 \times 32)$
$Q_r = 42.8$ gpd

From well DM-4 to MW-5B (Figure 11) - south of the river at low tide;

$Q_s = (3000/27) \times (1.5/700) \times (1 \times 27)$
$Q_s = 6.4$ gpd

$Q_r - Q_s$ = to water lost by III_A per foot width in the vicinity of the river:
$Q_r - Q_s$ = 36.4 gpd

To estimate the total discharge of Unit III_A to the Christina River in the area of the Newport Site:

$Q_t = (Q_r - Q_s) \times$ length of North Disposal site
$Q_t = (42.8 \times 6.4) \times 1050$
$Q_t = 38,220$ gpd

A similar estimation for high tide (Figure 10) yields a difference in Q of 22,260 gpd over length of the Newport Site. In the area of the Newport Site the discharge to the river from Unit III_A is estimated to be on the order of 20,000 - 40,000 gpd. The data of the aquifer tests together with stratigraphic information, support interpretation of the piezometric head data which indicate that the Christina River is an effective hydrologic boundary.

Based on the estimated transmissivities, hydraulic gradients, and water-bearing zone thicknesses, groundwater flow velocities were evaluated using a formula derived from the Darcy equation. Within the Intermediate Zone (Unit III_A), groundwater flow velocities are estimated to range from about 0.2 to 0.4 ft/day north of the Christina River and about 0.2 to 0.6 ft/day south of the Christina River.

4.0 CONCLUSIONS

The subsurface geologic, stratigraphic, and geophysical data collected at the Newport Site, together with the hydrologic data, provide ample information on the groundwater hydrology to allow assessment of groundwater flow potentials and an estimation of groundwater flow paths relative to the North Disposal site. The data on the Newport site confirm the hydrologic and geologic analyses performed by others on the region (Petty et al., 1983; Woodruff 1981, 1984, 1985).

Strata at the Newport Site are divided into five hydrostratigraphic units that are correlative with the Columbia Formation (Unit I), the middle clay member of the Potomac Formation (Unit II), the lower sandy member of the Potomac Formation (Units III_A, III_B, and IV), and decomposed bedrock (Unit V). The water-bearing units at the Site include Unit I (Shallow Zone), which is an unconfined (water table) water-bearing unit, and Units III_A (Intermediate Zone), and IV (Deep Zone), which are confined or semi-confined water-bearing units. Aquitards include Units II and III_B.

Infiltration north of the Christina River at the site apparently percolates into the Shallow Zone (Unit I) and discharges to the Christina River. Vertical groundwater flow north of and underneath the Christina River is upward from Unit III_A into the Unit I and to the

Christina River, which is a groundwater discharge area. No groundwater flow path extending from the North Disposal site to the water-bearing units of the Potomac Formation has been identified.

Data of the aquifer tests, in combination with the stratigraphic and piezometric head data of the Site indicate a groundwater loss on the order of 20,000 to 40,000 gpd to the Christina River in the area of the Newport plant landfill. Based on aquifer tests, the groundwater flow velocities in the Intermediate Zone (Unit III_A) are estimated to range from about 0.2 to 0.4 ft/day on the north side of the Christina River and about 0.2 to 0.6 ft/day south of the Christina River.

5.0 LIMITATIONS

The findings and conclusions presented in this report are based upon the interpretations developed from this study and the available geologic, subsurface and groundwater data. These findings and conclusions would be subject to further confirmation and/or revisions if additional information becomes available.

6.0 REFERENCES

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Tables

TABLE 1

HYDROSTRATIGRAPHIC UNITS
Du Pont Newport Site

Unit	Lithologic Appearance	Depth Range to top of Unit	Unit Range of Thickness
I	Shallow Zone. (Columbia Formation; Pleistocene) Clastics, yellow brown to orange sands and clays. Usually clayey near land surface, grading coarser with depth. This unit often contains a gray-black organic clay.	0	25-34
II	Semi-Confining Unit. (Top of Potomac Formation; Cretaceous) Marked by the first appearance of white-gray sand or reddish to orange sandy clays. Appears to be an effective semi-confining unit separating Unit I and Unit III_A.	25-34	23-40
III_A	Intermediate Zone. Clayey sand unit, consisting of clayey sands in the upper section grading to a more clayey unit with depth. Sands range from fine to medium grained with varying clay content. Color ranges from red to orange to yellow.	53-66	13-37
III_B	Semi-Confining Unit. This unit is very similar to III_A in color and shows interfingering of units except that the clay content increases significantly in the lower portion of this unit. The top of this unit is marked by a violet-red, manganese-stained clay. Appears to be an effective semi-confining unit separating Units III_A and IV.	75-93	10-39
IV	Deep Zone. Usually contains a white and light gray to orange medium clayey sand, up to ten feet in thickness overlying the bedrock. This unit may contain red dense clays and/or black organic-rich layers generally less than 18 inches thick.	90-118	15-30
V	Decomposed Bedrock. Olive green, friable, weathered schist and gneiss occasionally overlain by off-white clay. Probable low permeability; unit probably acts as base to active flow system.	110-140	10-40+

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TABLE 2

PRE-EXISTING ACTIVE MONITORING WELLS
Du Pont - Newport Plant Landfill

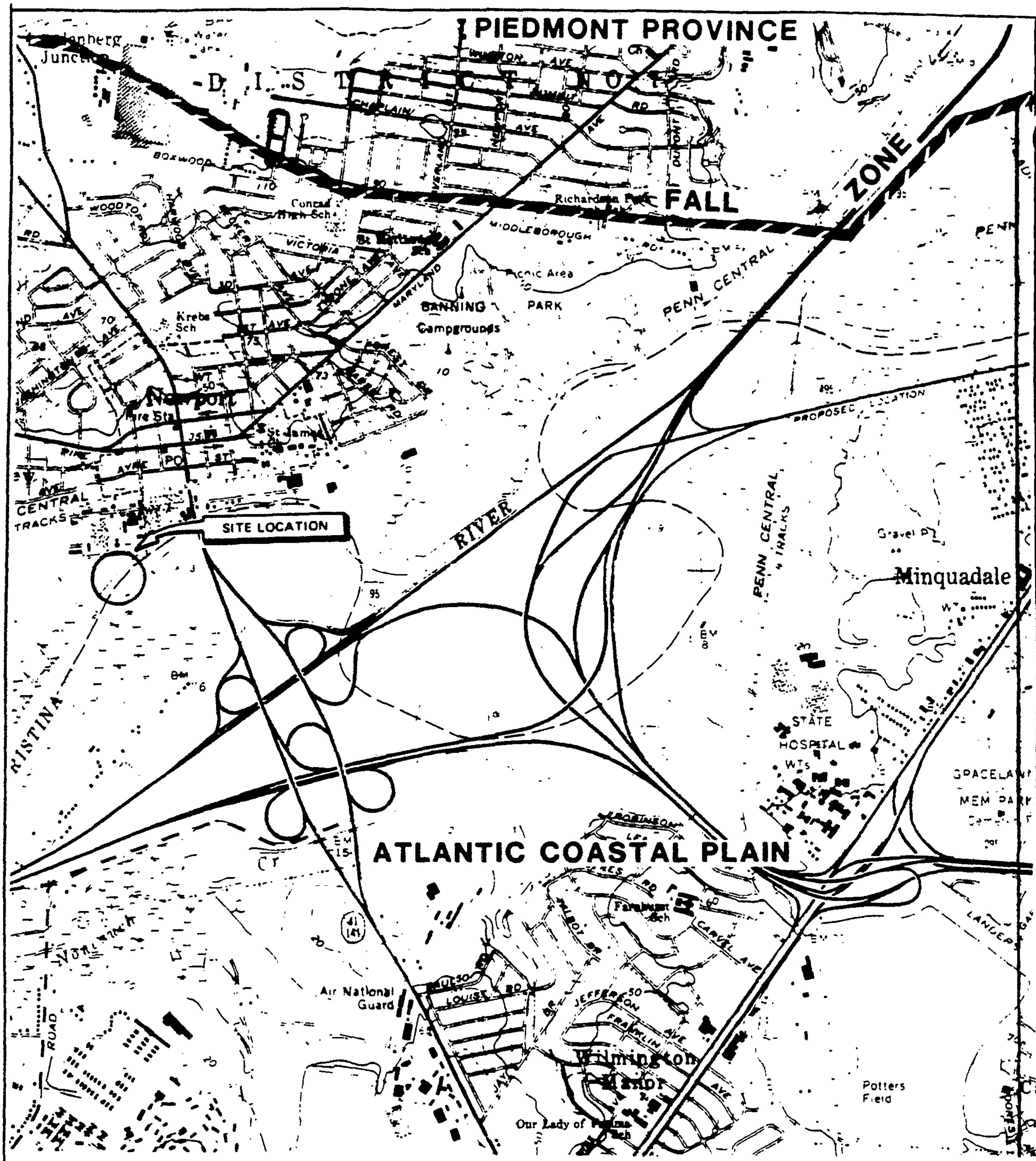
Well Designation	Total[3] Depth	Screened[3] Interval	WCC Hydrostratigraphic Unit[4]
SM-1	24'	17' - 21'	I
SM-2	25'	21' - 25'	I
SM-3	35'	31' - 35'	I
SM-4[1]	51'	20' - 25'	I
SM-5	20'	15' - 20'	I
DM-4	50'	44' - 50'	III_A
DM-6	70'	60' - 70'	III_A
DMU-7	50'	40' - 50'	II
DML-7	155'	135' - 145'	IV
DM-8	126'	45' - 55'	II
WW-11[2]	65'	50' - 60'	III_A
WW-13[2]	112'	88' - 99'	III_B

1) Formerly DM-2; reclassified as SM-4 due to screened interval in Columbia.
2) Not utilizied for supply purposes since approximately 1980.
3) Total depth and screened interval data supplied by Du Pont and and not verified by WCC.
4) Woodward-Clyde Consultants (WCC) Hydrostratigraphic Units relate to monitoring zones as follows:

Shallow Zone	=	I
Intermediate Zone	=	III_A
Deep Zone	=	IV

WM-44I

Figures



0 1000 2000 FT
SCALE

SOURCE: WOODRUFF (1984)

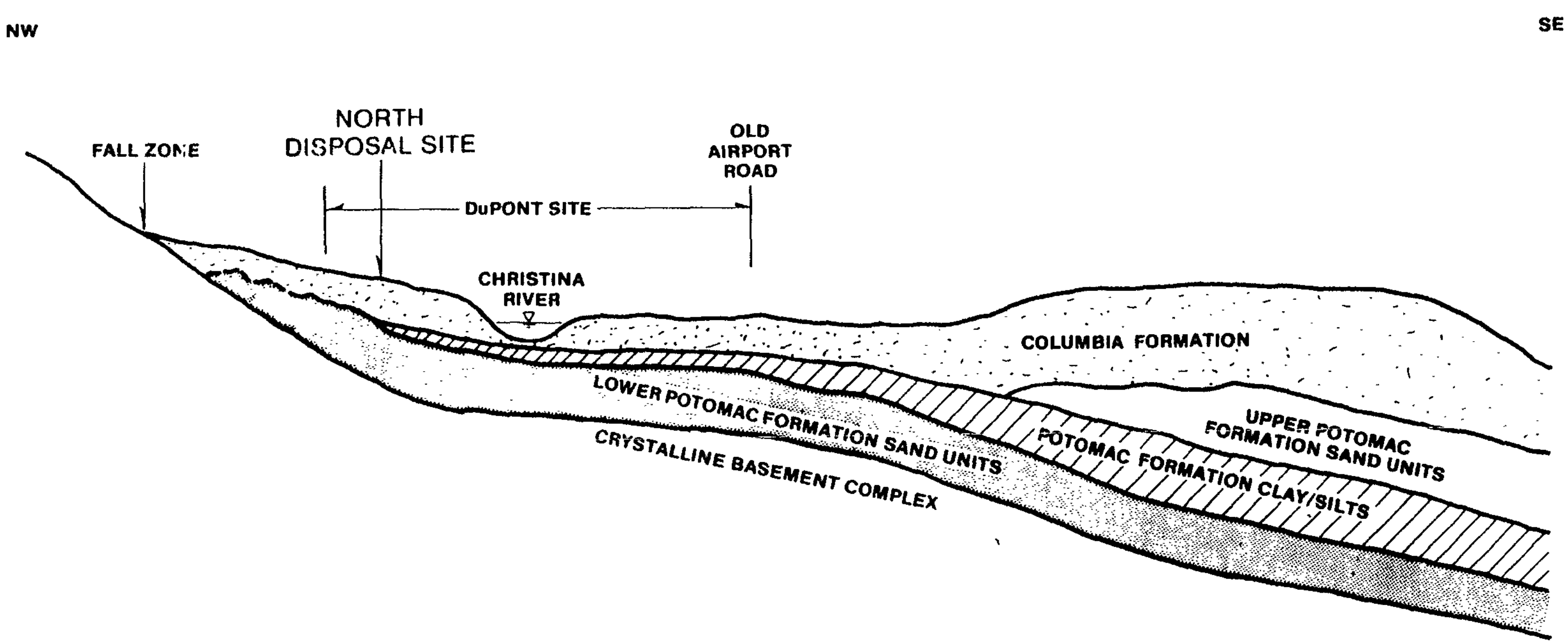
N

PHYSIOGRAPHIC PROVINCES
AFTER PETTY, ET. AL. (1983)
duPONT-NEWPORT SITE

WOODWARD - CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
WAYNE NEW JERSEY

DR BY	TJD	SCALE	AS SHOWN	PROJ NO	88C2076-2
CK'D BY	JR	DATE	14 MARCH 1987	FIG NO	Figure 1



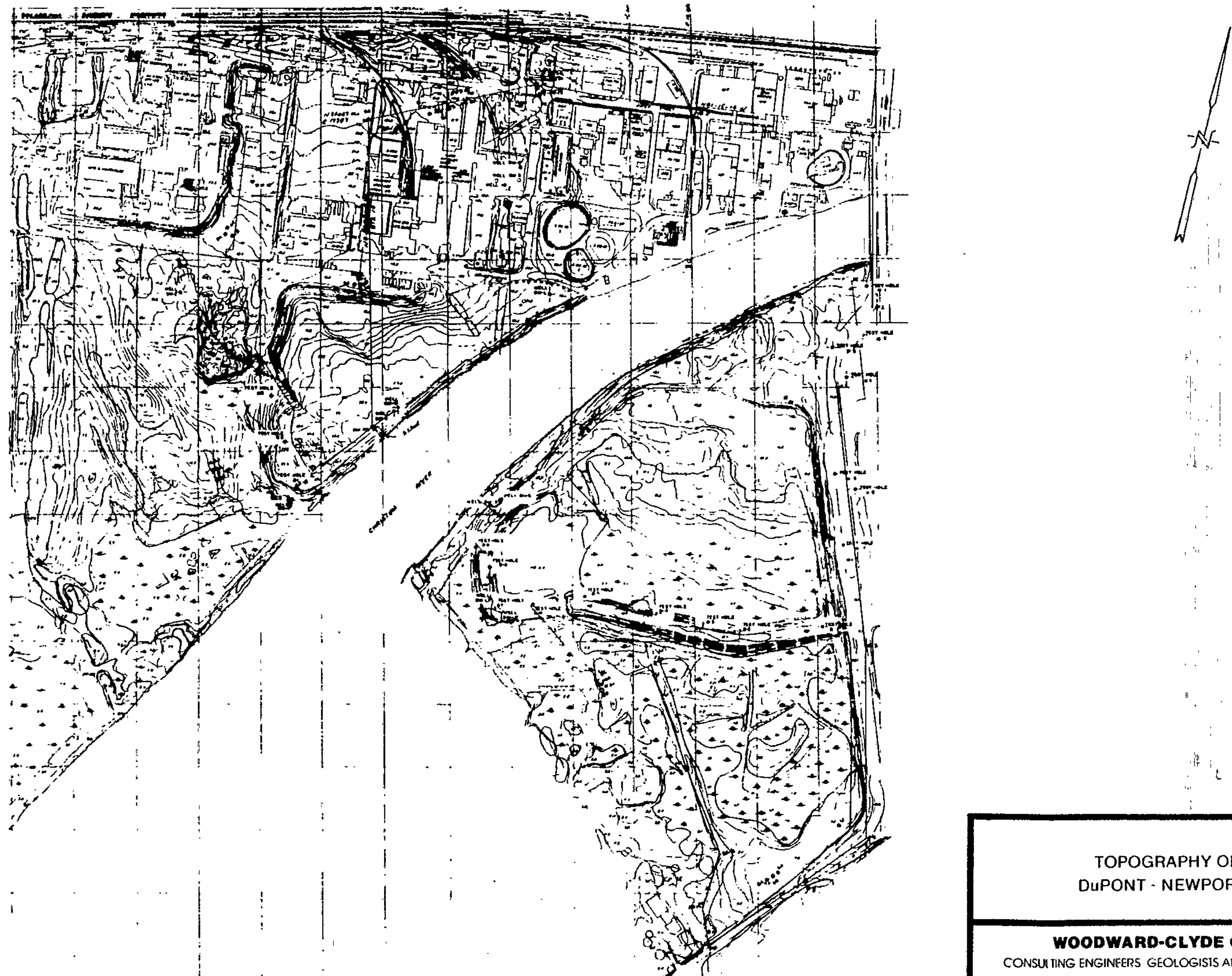
NOTES:
AFTER WOODRUFF, 1985
THE EXTENSION OF THE POTOMAC FORMATION CLAYS AND SILTS NORTH OF THE CHRISTINA RIVER BASED ON DATA FROM THIS NEWPORT SITE INVESTIGATION

DIAGRAMATIC CROSS-SECTION OF STRATIGRAPHY
DuPONT - NEWPORT SITE
NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET	Date 9/2/87	
Checked by R.G.	N.T.S.	Job 88C2076-2	

FIGURE 2

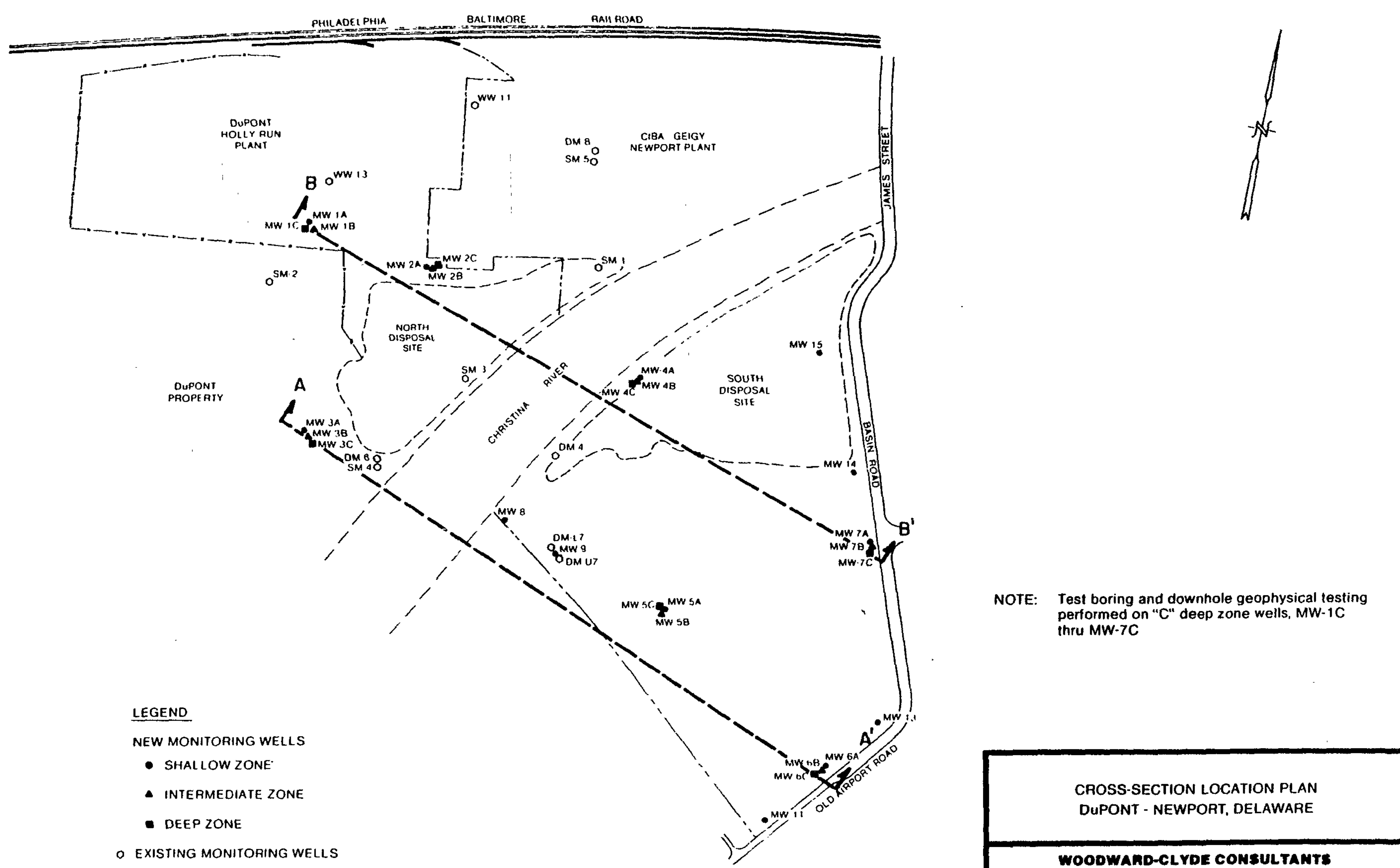


TOPOGRAPHY OF SITE AREA
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	SCALE IN FEET	Date	9/3/87
Checked by J.B.	0 400	Job	88C2076-2

FIGURE 3



NOTE: Test boring and downhole geophysical testing performed on "C" deep zone wells, MW-1C thru MW-7C

CROSS-SECTION LOCATION PLAN
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	T P	SCALE IN FEET	Date	9/ 2 /87
Checked by	R T G	0 400	Job	86C2076-2

FIGURE 4

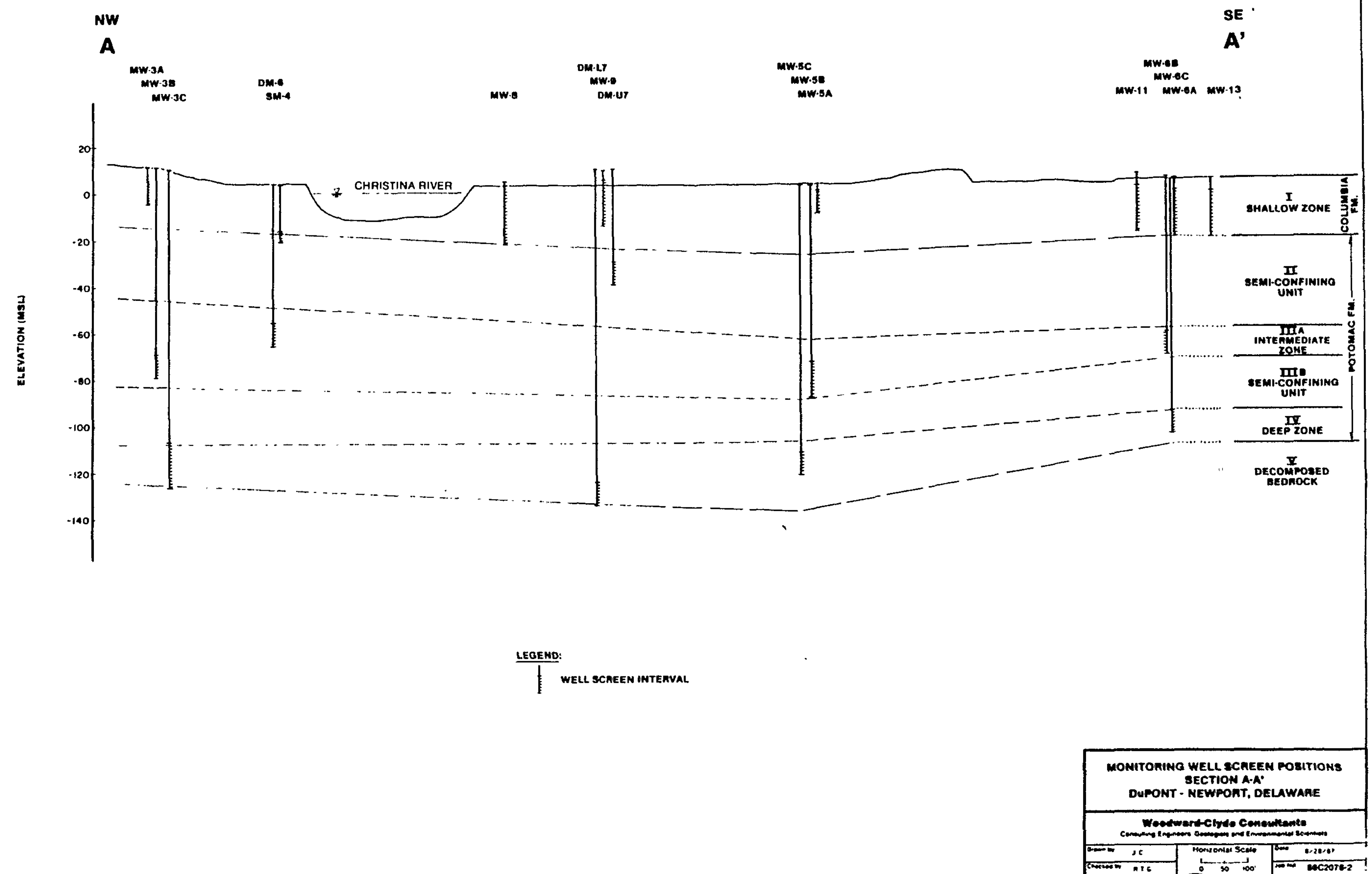
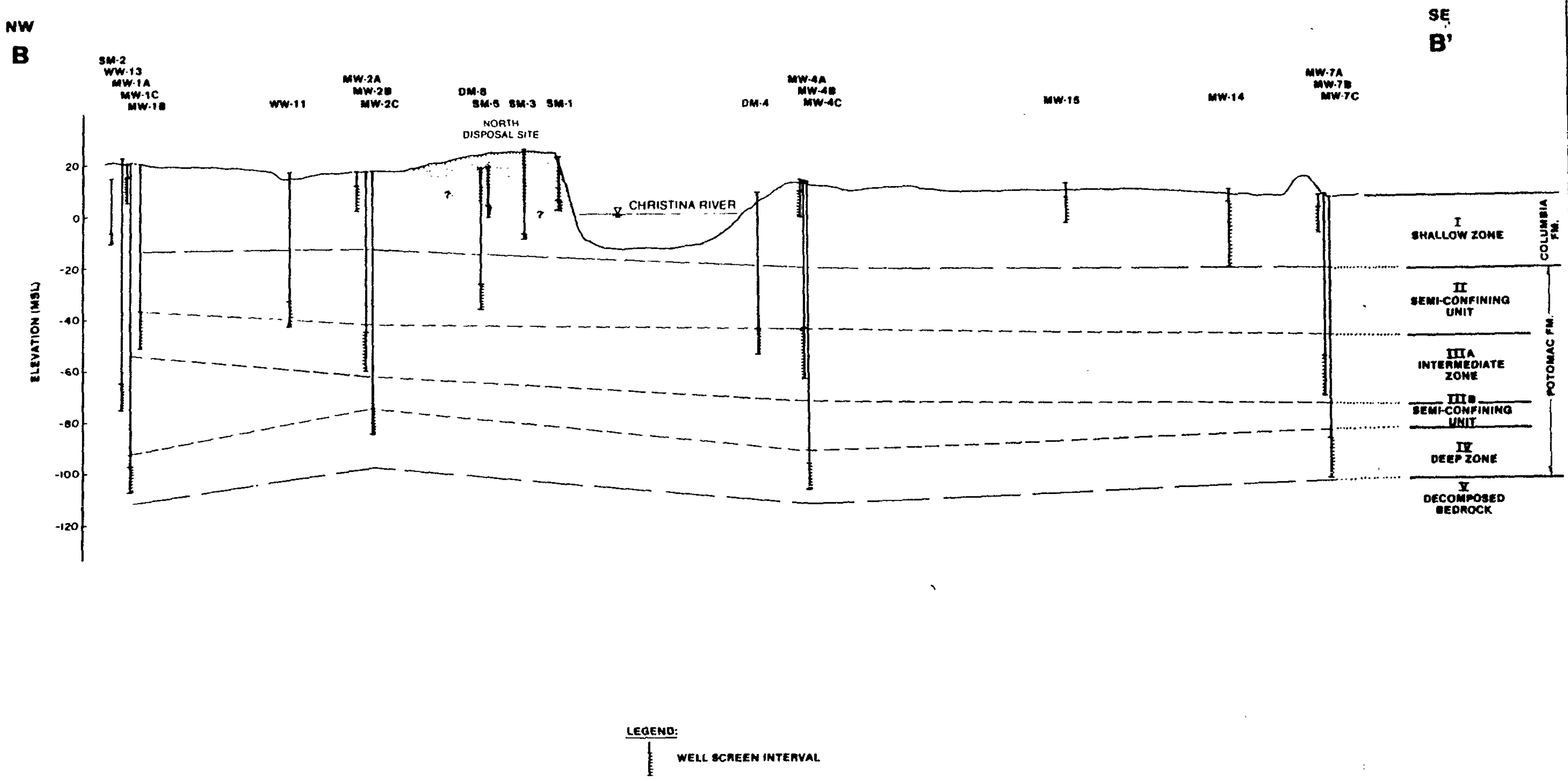


FIGURE 5

AR301112



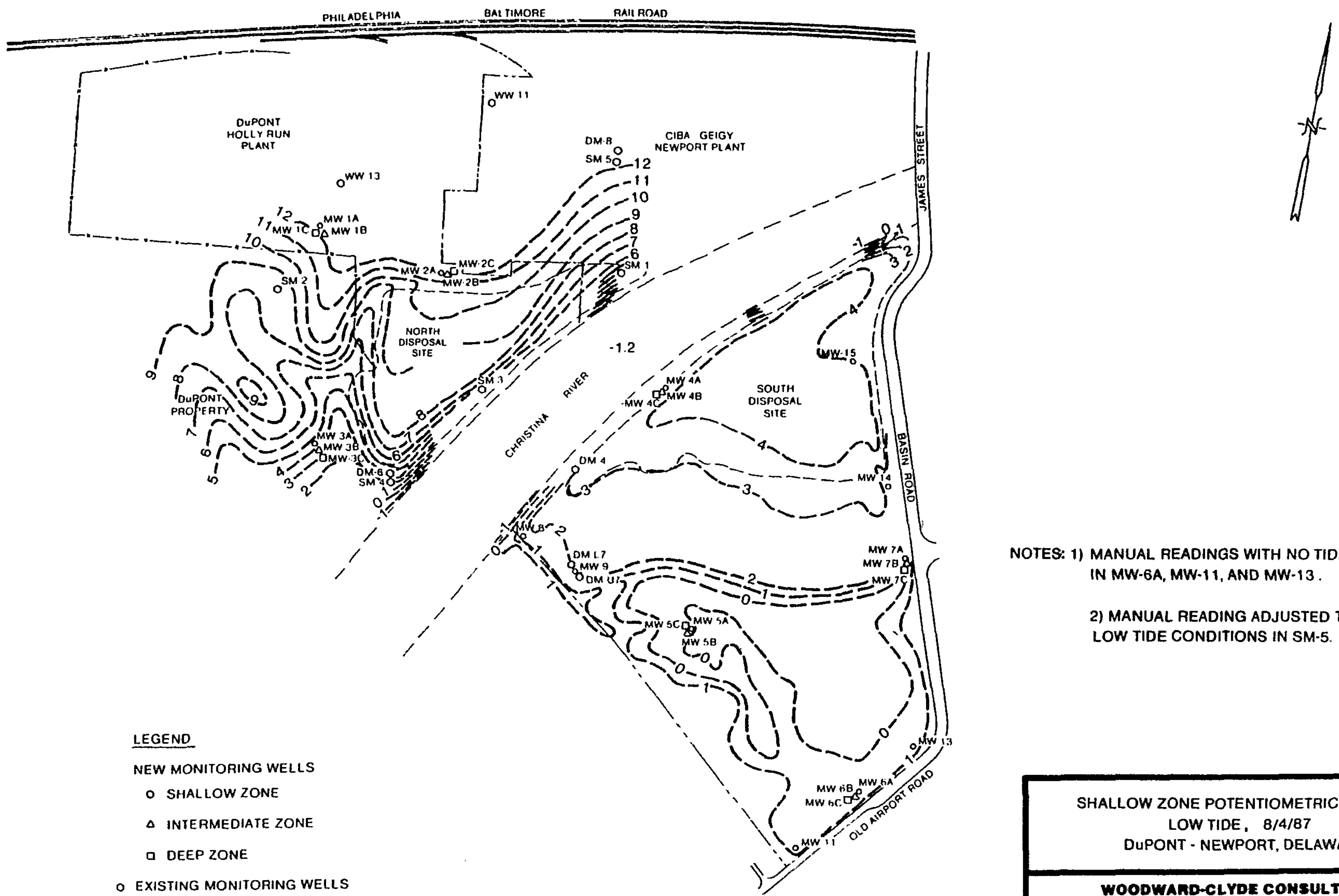
MONITORING WELL SCREEN POSITIONS
SECTION B-B'
DuPONT - NEWPORT, DELAWARE

Woodward-Clyde Consultants
Consulting Engineers Geologists and Environmental Scientists

Drawn by DEG	Horizontal Scale	Date 6-26-87	
Checked by RTG	0 50 100'	Job No. 88C2076-2	

FIGURE 6

AR301113



NOTES: 1) MANUAL READINGS WITH NO TIDAL INFLUENCE IN MW-6A, MW-11, AND MW-13.

2) MANUAL READING ADJUSTED TO 8/4/87 LOW TIDE CONDITIONS IN SM-5.

LEGEND

NEW MONITORING WELLS

- o SHALLOW ZONE
- △ INTERMEDIATE ZONE
- □ DEEP ZONE

o EXISTING MONITORING WELLS

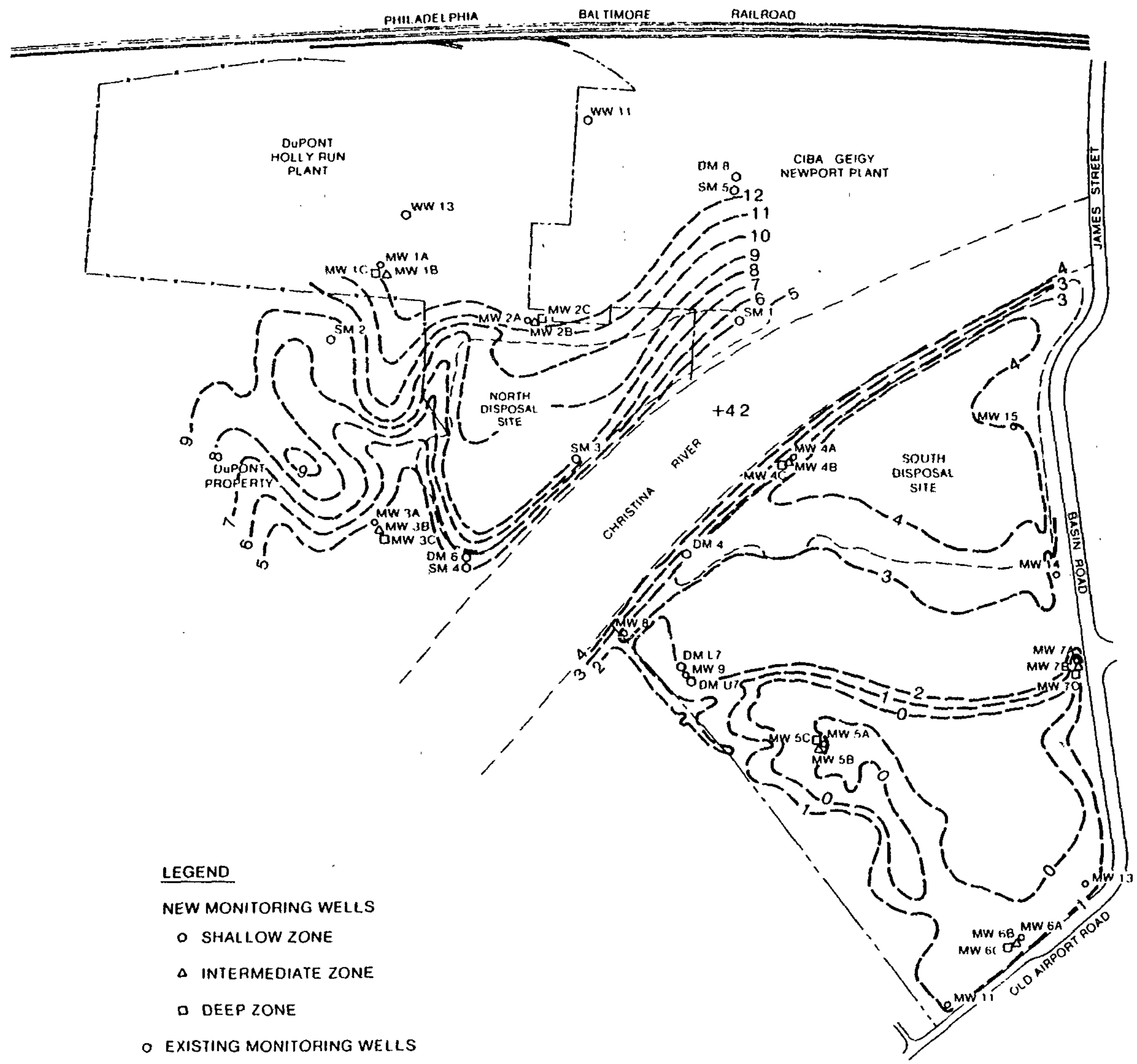
3— — — POTENTIOMETRIC SURFACE ELEVATION (MSL)

SHALLOW ZONE POTENTIOMETRIC SURFACE
LOW TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by T P	SCALE IN FEET 0 — 400	Date 8/26/87
Checked by R T G.		Job 86C2076-2

FIGURE 7



NOTES: 1) MANUAL READINGS WITH NO TIDAL INFLUENCE IN MW-6A, MW-11, AND MW-13.

2) MANUAL READING ADJUSTED TO 8/4/87 HIGH TIDE CONDITIONS IN SM-5.

LEGEND

NEW MONITORING WELLS

- o SHALLOW ZONE
- Δ INTERMEDIATE ZONE
- □ DEEP ZONE

o EXISTING MONITORING WELLS

3 — — — POTENTIOMETRIC SURFACE ELEVATION (MSL)

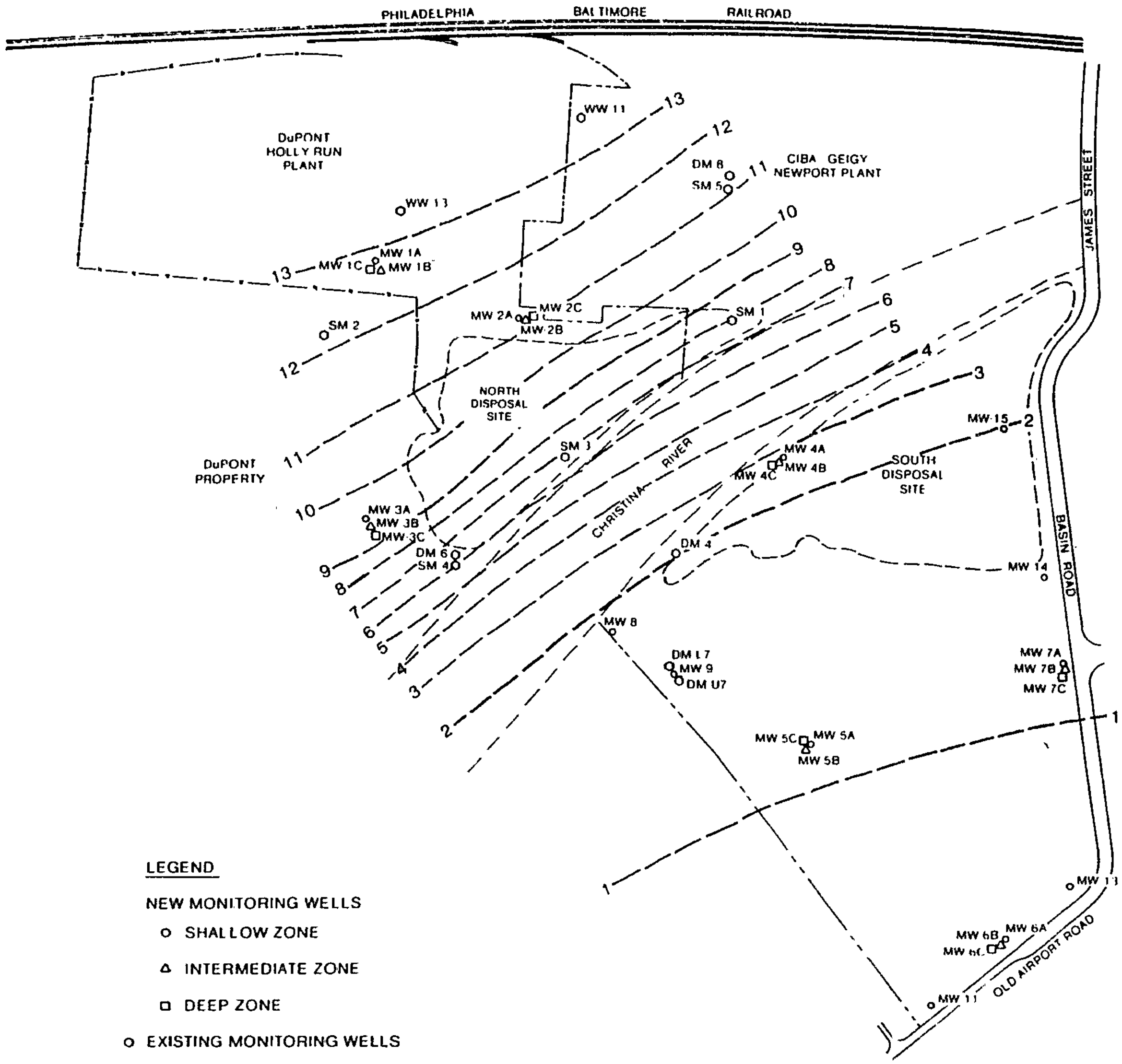
SHALLOW ZONE POTENTIOMETRIC SURFACE
HIGH TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by T P	SCALE IN FEET 0 — 400	Date 8/26/87	
Checked by R T.G		Job 88C2076-2	

FIGURE 8

AR301115



NOTES: 1) MANUAL READING ADJUSTED TO 8/4/87
LOW TIDE CONDITIONS IN DM-8.

LEGEND

NEW MONITORING WELLS

- o SHALLOW ZONE
- Δ INTERMEDIATE ZONE
- □ DEEP ZONE

o EXISTING MONITORING WELLS

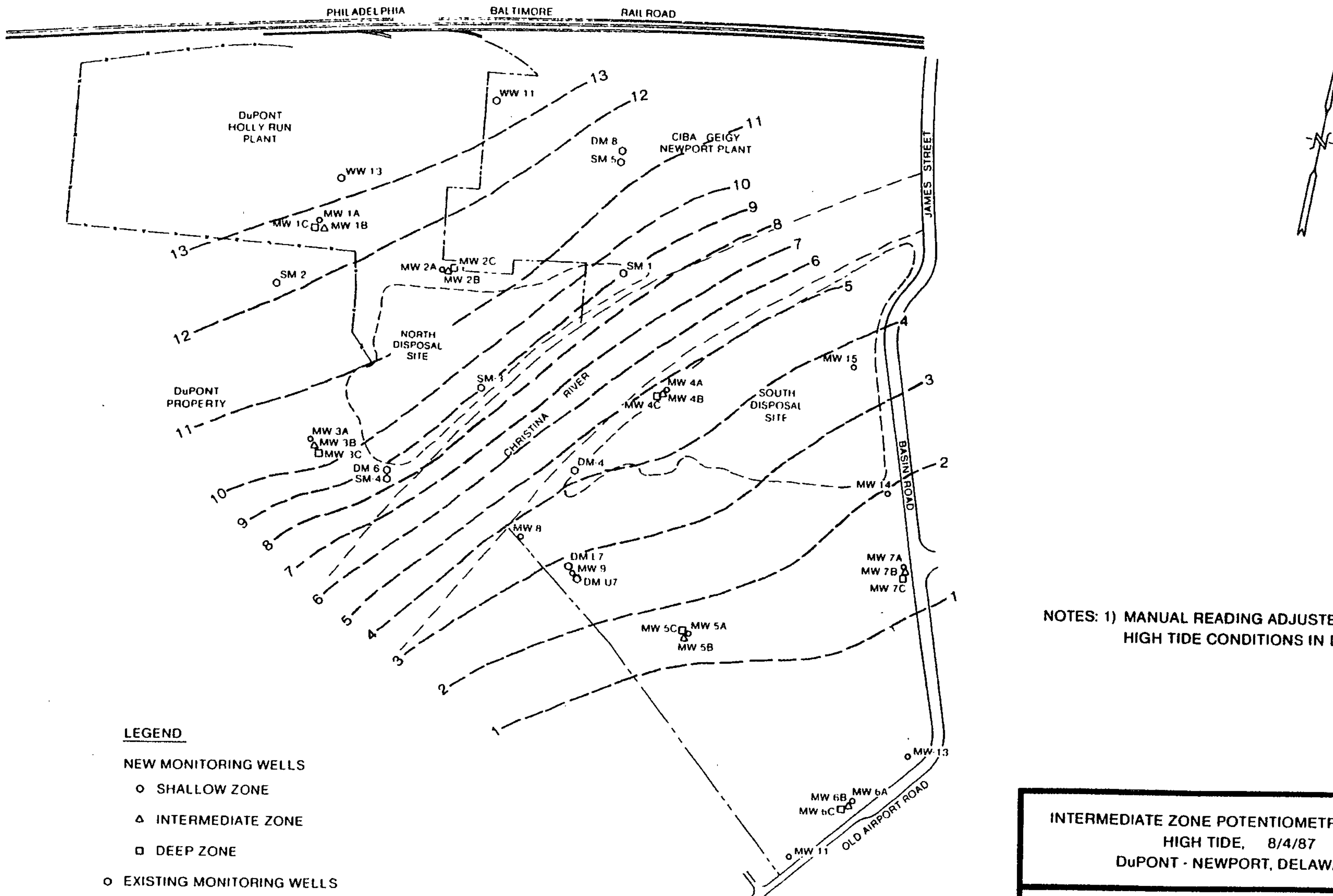
3———POTENTIOMETRIC SURFACE ELEVATION (MSL)

INTERMEDIATE ZONE POTENTIOMETRIC SURFACE
LOW TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by T P	SCALE IN FEET	Date	8/26/87
Checked by R T G	0 400	Job	86C2076-2

FIGURE 9



NOTES: 1) MANUAL READING ADJUSTED TO 8/4/87 HIGH TIDE CONDITIONS IN DM-8 .

LEGEND

NEW MONITORING WELLS
- o SHALLOW ZONE
- Δ INTERMEDIATE ZONE
- □ DEEP ZONE

o EXISTING MONITORING WELLS

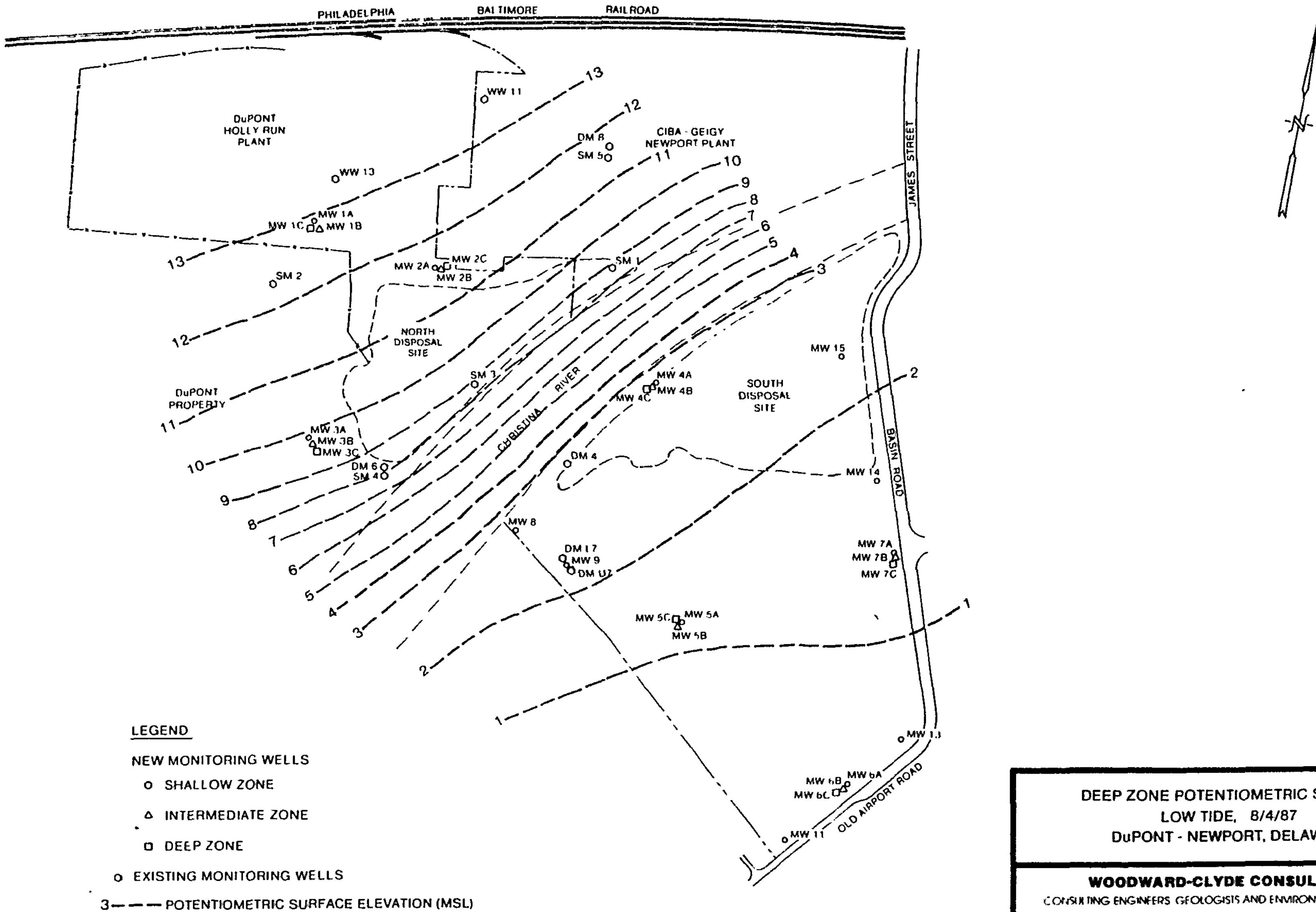
3— — —POTENTIOMETRIC SURFACE ELEVATION (MSL)

INTERMEDIATE ZONE POTENTIOMETRIC SURFACE
HIGH TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	T P	SCALE IN FEET	Date	8/26/87
Checked by	R T.G	0 400	Job	86C2076-2

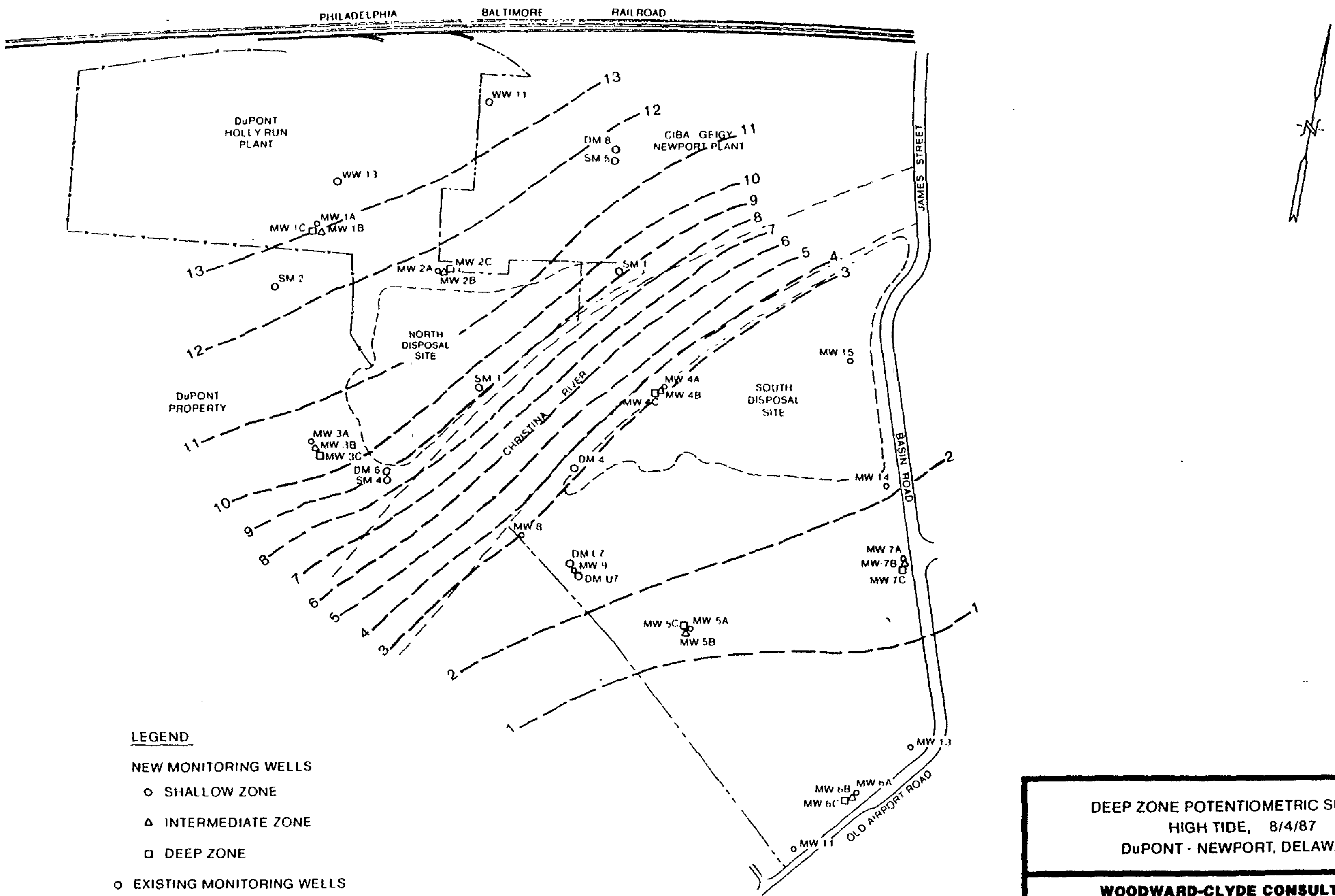
FIGURE 10



DEEP ZONE POTENTIOMETRIC SURFACE LOW TIDE, 8/4/87 DuPONT - NEWPORT, DELAWARE		
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS		
Drawn by T P	SCALE IN FEET 0 400	Date 8/26/87
Checked by R T G		Job 88C2076-2

FIGURE 11

AR301118



LEGEND

NEW MONITORING WELLS

- o SHALLOW ZONE
- △ INTERMEDIATE ZONE
- □ DEEP ZONE

o EXISTING MONITORING WELLS

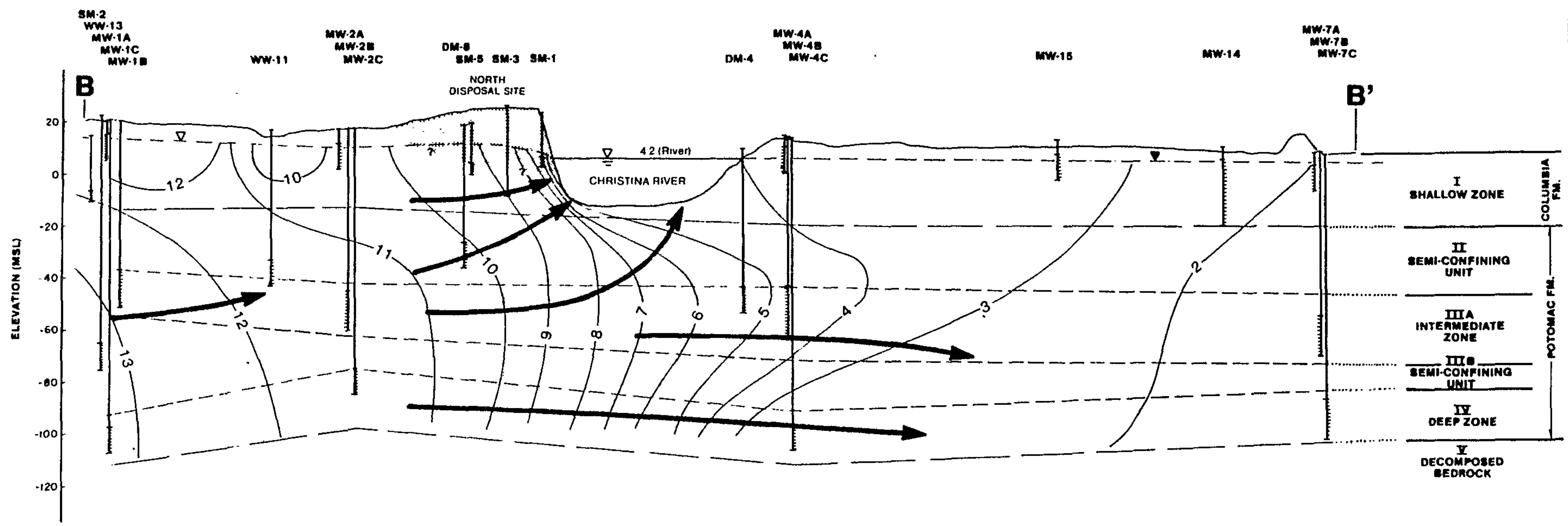
3 — — — POTENTIOMETRIC SURFACE ELEVATION (MSL)

DEEP ZONE POTENTIOMETRIC SURFACE
HIGH TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by T P	SCALE IN FEET 0 — 400	Date 8/26/87	
Checked by R T G		Job 86C2076-2	

FIGURE 12



LEGEND

- WELL SCREEN INTERVAL
- 8 CONTOURS OF HEAD (MSL)
- DIRECTION OF GROUNDWATER FLOW
- ▽ RIVER WATER ELEVATION
- ▼ WATER TABLE

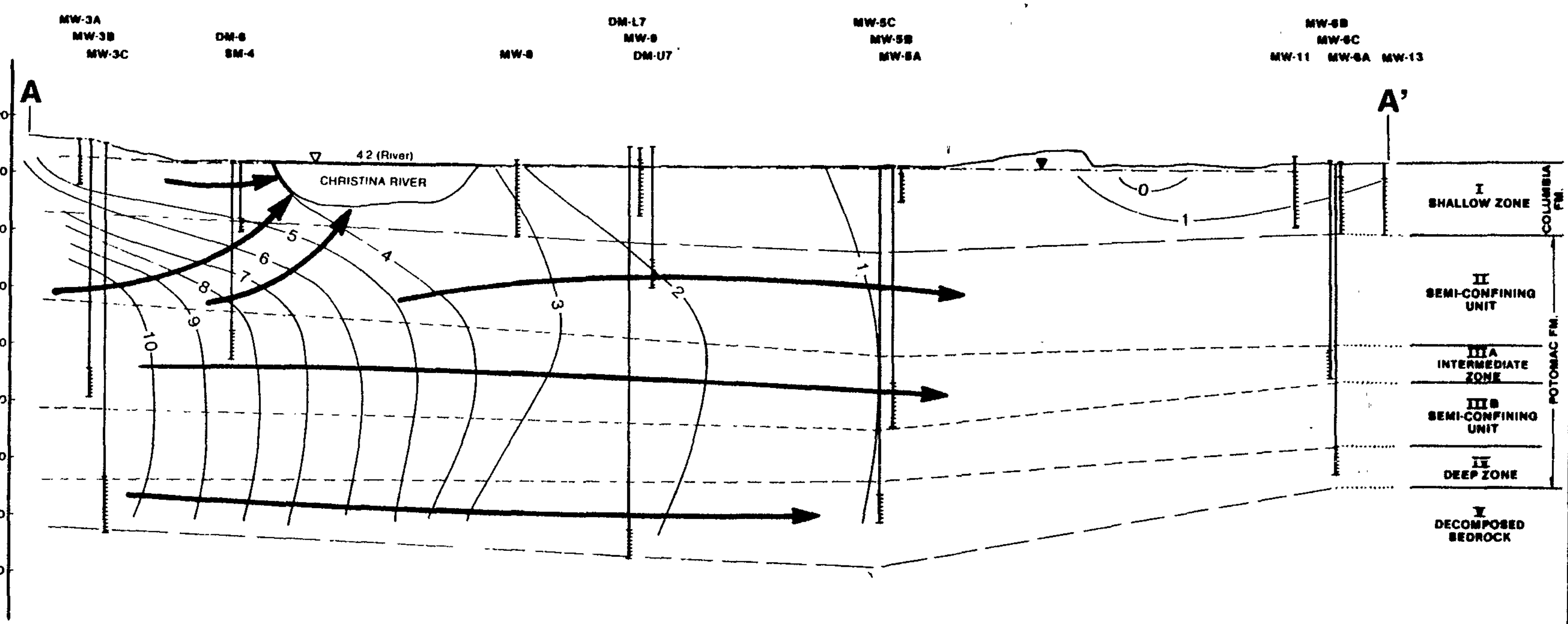
NOTES High tide means time of highest river level.
Data based on potentiometric contours shown on other figures

POTENTIOMETRIC HEAD CONTOURS
SECTION B B'
HIGH TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by BE6	Horizontal Scale 0 50 100'	Date 8/28/87	
Checked by BT6		Job No. 88C2078-2	

FIGURE 15



LEGEND

- WELL SCREEN INTERVAL
- 3 CONTOURS OF HEAD (MSL)
- DIRECTION OF GROUNDWATER FLOW
- ▽ RIVER WATER ELEVATION
- ▼ WATER TABLE

NOTES High tide means time of highest river level

Data based on potentiometric contours shown on other figures

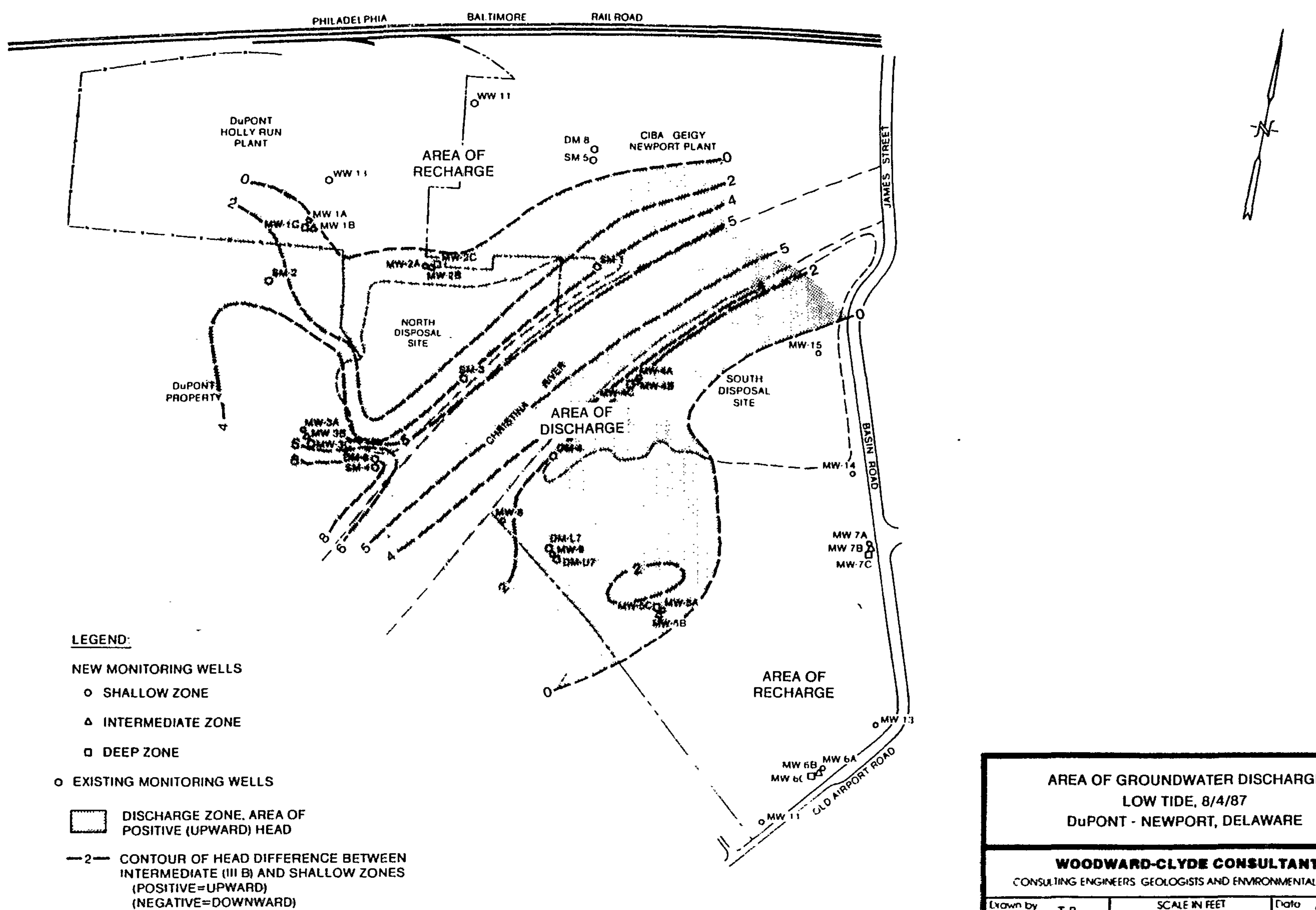
POTENTIOMETRIC HEAD CONTOURS
SECTION A-A'
HIGH TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by J.C.	Horizontal Scale 0 50 100'	Date 8/28/87
Checked by R.T.G.		Job No. 88C2078-2

FIGURE 16

AR301123



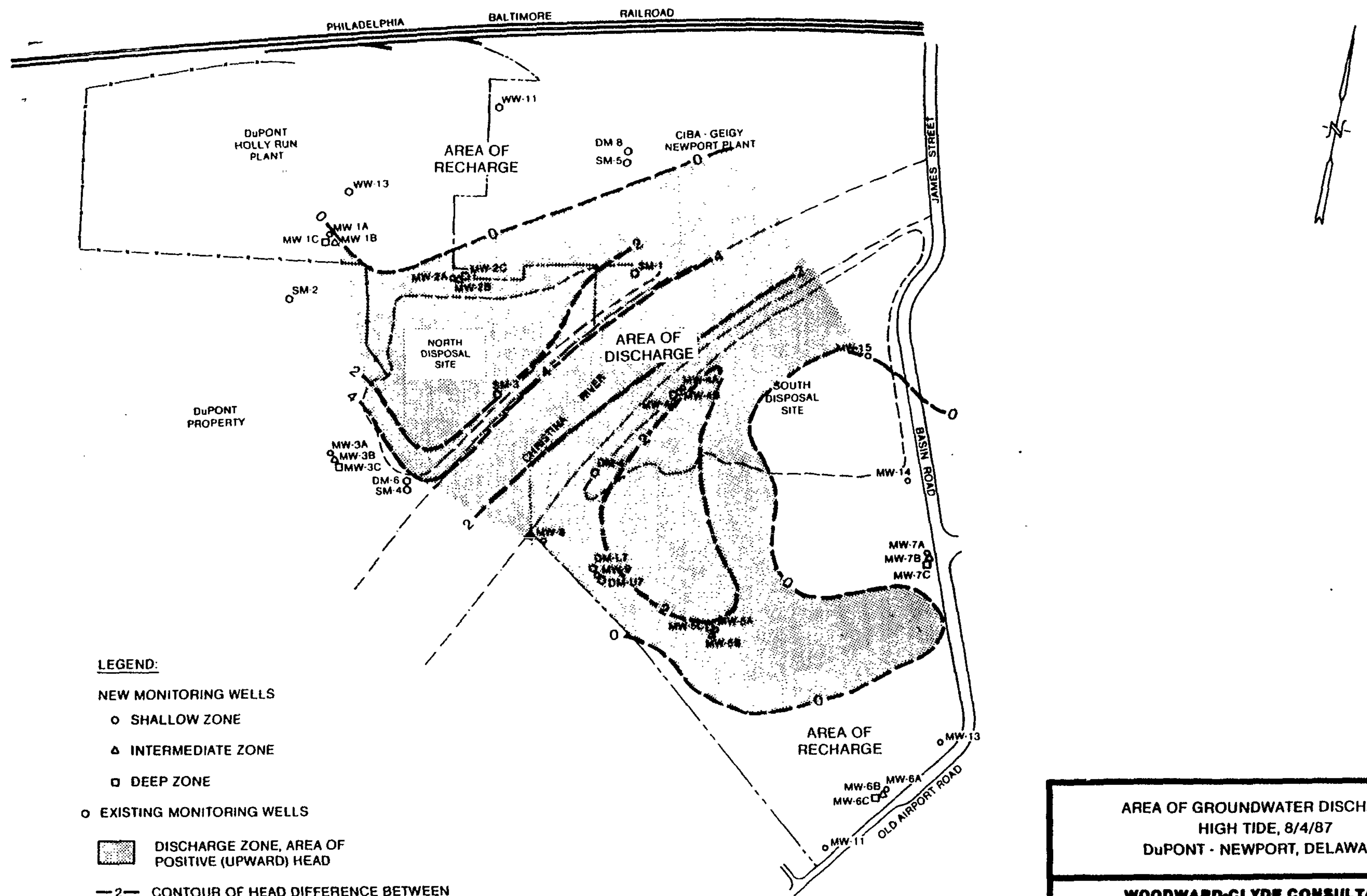
AREA OF GROUNDWATER DISCHARGE
LOW TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by T P	SCALE IN FEET 0 400	Date	9 / 2 /87
Checked by R T G		Job	88C2076-2

FIGURE 17

AR301124



LEGEND:

NEW MONITORING WELLS

- o SHALLOW ZONE
- △ INTERMEDIATE ZONE
- ▫ DEEP ZONE

o EXISTING MONITORING WELLS

▒ DISCHARGE ZONE, AREA OF POSITIVE (UPWARD) HEAD

—2— CONTOUR OF HEAD DIFFERENCE BETWEEN INTERMEDIATE (III B) AND SHALLOW ZONES
(POSITIVE=UPWARD)
(NEGATIVE=DOWNWARD)

AREA OF GROUNDWATER DISCHARGE
HIGH TIDE, 8/4/87
DuPONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	P	SCALE IN FEET 0 — 400	Date	9 / 2 /87
Checked by	R T G		Job	88C2076-2

FIGURE 18

AR301125

Borehole Geophysical Logging
Du Pont Newport Site
Newport, Delaware

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1.0 DATA OBJECTIVES

The purpose of the borehole geophysical logging program at the Site was to identify potential water-bearing zones between land surface and bedrock and to assess the continuity of the hydrostratigraphic units across the study area. A suite of five logs was selected to meet the objectives including:

- single point resistance log;
- natural gamma ray log;
- epithermal neutron log;
- compensated density log; and
- caliper log.

Seven boreholes (test borings, TB-1 through TB-7) were logged from land surface into weathered bedrock at both the North and South Disposal sites (TB-1, 2, and 3 north of the Christina River and TB-4, 5, 6 and 7 south of the river). The borehole geophysics logs are presented in Figures 1 through 7.

2.0 FIELD METHODS

2.1 LOGGING

Test borings (TB) were drilled into bedrock at seven locations. Split-spoon samples were taken on five-foot centers to total depth through six inch or eight inch hollow stem augers. Lithologic logs of the test borings were prepared based on sample descriptions. Samples ranged in length from a few inches to up to full recovery of 2-1/2-feet. Although sampling was not continuous the contacts between formations and hydrostratigraphic units were generally gradational and the samples collected provided good representation of the sediments drilled. Samples from the split-spoons were placed in glass jars for later comparison with the borehole geophysical logs.

Once total depth into bedrock was attained, the hollow stem augers were withdrawn and the hole was geophysically logged. Data from the lithologic and geophysical logs were then utilized to determine which zones to screen. The logged borehole was then converted to the deepest monitoring well and adjacent shallow and intermediate zone wells were drilled in close proximity to the deep well.

2.2 DECONTAMINATION

Prior to arriving at the Newport Site, the geophysical logging equipment (cable, probes, etc.), were decontaminated. Logging tools were also decontaminated after each test boring or monitoring well was logged, using a multiple of two washes with an alconox and distilled water solution, then rinsed with distilled water before being placed in the next test boring or monitoring well. After the test borings were logged, the probes were returned to their dedicated storage places in the logging truck. The cable was rinsed with the above solution as it was retrieved from the test boring. All contaminated materials including disposable protective equipment and used decontamination fluids were disposed of in accordance with the Woodward-Clyde Health and Safety Plan.

2.3 CALIBRATION

The borehole geophysical probes were calibrated at the beginning and end of each well. Calibration for the natural gamma, neutron and density are via internal electronics where actual pulses emitted from the probe are compared to known internal standards. The calibration of the single-point resistance log also utilizes the internal electronics but the output is quantified using a potentiometer to record the resistivity on a linear scale. The caliper log is calibrated at the beginning of each cluster with a calibration bar for multiple known diameters. The best probable method for evaluating if a log is functioning properly is to rerun either portions of the borehole or the entire log and compare the results for repeatability. This method was conducted on several wells at the Newport Site and produced results, in all cases, within the limits of the respective probes.

In addition to the field calibration checks and in accordance with WCC well logging QA/QC program, the probes are periodically run in a test borehole and checked for their ability to duplicate previous runs. Large changes in borehole diameter affect the various logs to different degrees depending upon the probe's radii of investigation, magnitude of borehole diameter change and the abruptness of diameter change (thin streaks, wide washouts, etc.). Correcting for these changes is usually not critical to semi-qualitative interpretation conducted in water resource investigations and are usually not carried out. Although the caliper log "appears" to show a wide range in borehole diameter on some of the logs run, the horizontal diameter is exaggerated approximately 60 times the vertical dimension. The nature or character of the washouts also are relatively smooth (as opposed to short deep washouts) which tend to have a minimal effect on probe response. Comparison of the logs with the split-spoon samples collected from each boring, indicates that good correlation exists for the entire interval logged. Variations in borehole diameter did not hinder the use of the logs for lithologic correlation between boreholes.

2.4 HEALTH AND SAFETY

Two radioactive sources were used in each monitoring well. The neutron probe utilized an Americium-Berilium source (1.0 Curie) that emits high-speed neutrons. The density probe employs a 0.125-Curie cesium source that emits gamma rays. The Health and Safety program and monitoring for these two sources are covered under the Woodward-Clyde Consultants Radiation Safety Program, licensed in Texas, and are in compliance with Nuclear Regulatory Commission (NRC) guidelines. Results of the medical and site monitoring program revealed no problems incurred during the Newport logging.

3.0 PRINCIPLES OF LOGS EMPLOYED AT NEWPORT SITE

Five types of logs were selected for use at the Newport Site based upon prior knowledge of the lithologic character of the sediments present. The logs included single point resistance, natural gamma, epithermal neutron, compensated density and caliper logs. The following is a brief discussion of the physical operating principles for each of the logs.

3.1 SINGLE POINT RESISTANCE

One of the oldest and simplest of probes is the point resistance probe. Resistance logs record point contact resistance (in ohms) of the formation. The resistance measured is related by Ohms Law:

$$r = \frac{V}{I}$$

Where the resistance (r, in ohms) is equal to the voltage V (kept constant by internal electronics in the truck) divided by the current I (in amperes). Advantages of this log include its ability to be run on a single conductor cable and its relatively shallow radius of investigation which enables precise recording of formation contacts. The shallow radius of investigation is considered to be about two to three times the electrode diameter (about 3-inches depending upon the formation resistance). There are some disadvantages. First, even the smallest cavities (or washouts), where contact with the formation is temporarily broken during logging, greatly affect the log response. Second, caliper logs are necessary for proper log interpretation to eliminate zones of extraordinary diameter.

3.2 NATURAL GAMMA

The natural gamma log was first introduced to the logging industry in 1939 and has since become the most widely used log in the water well industry. Although any attempt to quantify measurements from this log would be highly subjective, the gamma is an important probe for use in hydrostratigraphic correlations. The gamma log is often used to infer lithology, if the local geology is known.

The gamma log records natural gamma radiation emitted from formations adjacent to the borehole. The gamma radiation detected is primarily from the decay of three naturally occurring elements; potassium-40 (K^{40}) and from daughter isotopes in the uranium (U) and thorium (Th) decay series. Gamma rays received at the probe detector range in energy from approximately 0.5 MeV to 3.0 MeV. Most of the gamma energy received at the detector is less than 1.0 MeV. Gamma rays are extremely penetrating and are effectively used in cased and cemented wells, although a small correction factor may be necessary. Approximately 90 percent of the gamma rays recorded originate from within 18 inches of the borehole. The most common type of detector used in natural gamma probes is the scintillation type with a thallium-activated, sodium iodide crystal. Gamma rays are not differentiated into discrete energy ranges; therefore, the isotopes emitting the gamma rays (K, U, or Th) cannot be quantified or proportioned.

3.3 NEUTRON (POROSITY)

The neutron probe directly measures hydrogen saturation within the formation pore spaces. Since this study is concerned with the near-surface freshwater saturated formations, it is assumed that all of the hydrogen saturation is due to water rather than the presence of hydrocarbons. The neutron probe is equipped with a radioactive source (usually Am^{241}-Be) which constantly bombards the adjacent formation with high energy neutrons. These neutrons are constantly undergoing a de-energizing process as they collide with atoms comprising the formation and saturating fluids. The amount of energy lost during each collision is a function of the collision angle with the other atoms and the relative difference in mass. Since hydrogen atoms are relatively abundant and similar in mass to the neutron, the hydrogen ions are primarily responsible for the energy reduction, or the decrease in the number of neutrons counted at the detector.

Because many phenomena take place during the collision of a neutron with a hydrogen ion, such as lowering of thermal energy levels, emission of gamma rays from hydrogen atoms, etc., there are many types of neutron probes in use. The type of neutron probe most applicable to water resources investigations, and the type used in this study, is the neutron-epithermal neutron (N-E-N). This type of probe records the number of neutrons arriving at the detector (13-inches from the source) which have been thermalized to a lower energy state (0.1 to 100 eV) as a result of collisions with hydrogen atoms. The number of neutrons detected are exponentially related to the porosity of the formation and are scaled accordingly on the analog paper. Neutron probes have a relatively shallow radius of investigation (6-inch to 12-inch, decreasing with increased hydrogen content) and are greatly affected by the rugosity (roughness) of the borehole. A caliper log is necessary to correct for borehole diameter changes and to correct for zones with excessively large cavities.

3.4 COMPENSATED DENSITY

Density logging also employs an artificial radioactive source attached to the logging probe. The source is commonly a medium energy gamma emitter (Cesium-137) capable of penetrating 6 to 12-inches into the formation. Density logs, like neutron logs, are also a porosity type log measuring the electron density of the formation. As gamma rays collide with electrons, the frequency of Compton scattering collisions is directly related to the number of electrons within the formation and, in turn, is related to the bulk density. In order to calculate porosity from a density log, both the fluid density and matrix density must be known.

The type of density log employed at Newport was a decentralized probe with a side collimating detector window in contact with the borehole wall. Orienting the window toward the formation aids in eliminating the effects the borehole rugosity. The log records the number of gamma rays passing from the gamma emitting source, on the bottom of the probe, through the formation and back to detectors at 4-inch and 12-inch spacings above the source. The close source-detector spacing (4-inch) has a shallow radius of investigation, while the 12-inch detector will have a larger and deeper depth of investigation.

3.5 CALIPER

Caliper logs are primarily used to correct for changes in borehole diameter which directly affect the response of neutron, density, and single point resistance logs. Caliper logs are also used to estimate the relative induration of formations which is related to the type of lithology. The caliper log used at Newport was a decentralized single-arm type.

4.0 INTERPRETATION

4.1 METHODOLOGY

Borehole geophysical logs provide an indirect method for assessing changes in lithology and the hydrogeologic characteristics of the sediments penetrated in a borehole. One of the advantages of borehole geophysical logs includes the fact that logs provide a continuous measurement throughout the entire length of the borehole. They also record parameters not readily apparent to the naked eye. Because geophysical logs largely rely upon indirect measurements, it is most useful to compare the logs with cuttings, cores and drilling logs to provide the maximum benefit from the field data collection program. Interpretations with respect to hydrogeology at the Site in this section are based upon the interpretation of the logs by a certified well log analyst (Soc. Prof. Well Log Analysts No. 5851), drilling logs, split-spoon samples collected in glass sample jars and discussions with field geologists present during drilling of the test borings.

4.2 HYDROSTRATIGRAPHIC UNITS IDENTIFIED FROM GEOPHYSICAL LOGS

Based upon a comparison of the suite of borehole geophysical logs run at the Newport Site and the split-spoon samples, five "major" hydrostratigraphic units have been identified (Table 1). All five units have been identified in each of the seven test borings. However, the units commonly exhibit marked color and lithologic variation. The lithologies vary from thin bedded kaolinitic clays, to clayey silts, fine to coarse sands, gravels and cobbles. All of the sediments contain an appreciable amount of clay and only a few zones of limited thickness (typically less than 15 feet) are interpreted to be capable of moderate yields of water.

The division of sediments at the Site into units is considered subjective, and arguments can be made for "lumping" or "subdividing" the sequence further depending upon the preference of the user. For the purposes of this study, the units have been grouped according to gross hydrogeologic and stratigraphic characteristics. Variations in lithology within a particular unit may be considerable between boreholes, but the overall hydrostratigraphic characteristics are similar. The smaller members of these units appear to be lensoid on a scale of a few tens of feet or less. Table 2 shows the elevations, depths and thicknesses of these units in each of the seven test borings.

4.3 APPLICABILITY OF SELECTED LOGS TO HYDROSTRATIGRAPHIC UNITS

The borehole geophysical logs (Figures 1 through 7) are used to identify the individual hydrostratigraphic units based upon the physical characteristic(s) obtained from the logs. These criteria assess bulk resistivity of the saturated sediments (point resistance), natural gamma activity (gamma log), bulk porosity (neutron and density logs) and relative induration of the sediments (caliper log). The logs used at the Site are listed below by increasing order of relative importance in identifying the hydrogeologic units. Where applicable, specific comments about the response of individual tools to the sediments encountered at the Site are included. In addition, the geophysical characteristics and tool responses are provided on a unit by unit basis in Section 4.4.

4.3.1 SINGLE POINT RESISTANCE

Resistance and resistivity logs have traditionally proven to be excellent indicators of clay content in granular formations. Most clays are low in resistivity while quartz sands are highly resistive. Clays also generally have "higher" bulk porosity which tends to reduce bulk resistivity. These two factors combined account for the reason why the point resistance log was helpful at the Newport Site to delineate hydrogeologic units. Because large washouts along the borehole wall can seriously affect the validity of data collected, a caliper log was run to assess the rugosity of the borehole.

4.3.2 NEUTRON AND DENSITY LOGS

Both the neutron and density logs are sensitive to changes in porosity when the specific gravity of the lithologies logged are similar as they are at the Newport Site (kaolinite and quartz sands, 2.63 and 2.65 g/cc, respectively). The data from these logs proved to be useful at the Site by helping to identify the presence of clay as recorded on the resistance logs. Both of these types of radioactive logs are capable of penetrating approximately one foot into the borehole wall, or about three to four times the depth of investigation of the resistance log. In other words, these nuclear logs are less sensitive to borehole rugosity effects.

4.3.3 NATURAL GAMMA

Gamma logs are generally unaffected by changes in borehole diameter. The main problem with using the natural gamma log at the Newport Site is its apparent sensitivity to small changes in lithologic composition, such as thin bedded clays or certain assessory minerals. One possible example is the occurrence of small flakes of mica randomly concentrated in some of the sandy (coarser) sediments. Because muscovite mica is relatively rich in potassium, with an associated active gamma emitting isotope (K^{40}), it could be contributing to the total natural gamma response of the sediments. The signatures of the natural gamma logs, from the seven boreholes logged, show considerable variation across the Site and few gamma marker beds present.

4.3.4 CALIPER

Caliper logs are useful in assessing the induration (lithification or cementation) of formations drilled and serve as a check for large voids in the borehole which adversely affect the validity of data from logs with short radii of investigation. Clayey sections of the boreholes at the Site appeared to be more susceptible to washing and enlarging than sandy sections of the borehole.

4.4 GEOPHYSICAL CHARACTERISTICS OF HYDROSTRATIGRAPHIC UNITS

Unit I, Shallow Zone - Highly variable in both split-spoon samples and geophysical logs. Two members of the Columbia are of hydrogeologic significance: an upper water table sand (high resistance) and an underlying black to dark brown plastic, organic clay (low resistance) that appears to serve as an effective semi-confining or confining bed throughout the seven holes logged.

Unit II, Semi-Confining Unit - A clay matrix of low resistivity marks the top of this unit accompanied by a marked increase in porosity on the neutron and decrease in density on the density logs. As the middle of the unit is approached these trends tend to reverse due to a slight increase in sand content. The bottom of Unit II is marked by an increase of sand content grading into Unit III_A.

Unit III_A, Intermediate Zone - The upper part of Unit III contains 10 to 15 feet of sands of probable moderate permeability. This zone characteristically shows the highest resistance on the point resistance logs, the greatest density and lowest porosity of the sediments in the borehole. The zone of highest resistance within this unit was typically designated as the Intermediate Zone and was screened at each of the seven locations.

Unit III_B, Semi-Confining Unit - Separates the Shallow and Intermediate Zones. Unit III_B is similar in lithologic appearance to III_A but has a marked increase in clay content. The increase in clay content is most notable on the resistance logs, and is marked by an increase in neutron porosity, and a decrease in formation density. Interfingering of clayey sands and sandy clays is most prolific throughout Unit III (A and B).

Unit IV, Deep Zone - Lowermost producing zone overlying the weathered bedrock. The most characteristic member of this unit is an 8 to 12-foot producing zone known as the Deep Zone. The unit may or may not contain a thin, black, organic clayey unit and/or a highly plastic clay at the very base of the unit.

Unit V, Decomposed Bedrock - Weathered bedrock moderately indurated, olive green schist, characterized by low resistivity, moderate porosity and high density.

5.0 CONCLUSIONS

Although the clastic units overlying bedrock at the Newport Site are al predominantly clays, silts, and sands, the mapping of individual lithologic layers between all or even most wells cannot be done with a high degree of certainty. However, sequences of sediments can be grouped into the five distinct units that are recognized in each of the seven boreholes. Therefore, the individual units are interpreted as being either lenticular or else characterized by somewhat abrupt facies changes across the Site. Lithologic variability across the Site exists to the extent that there is a potential for leakage between the units overlying the bedrock; however, the extent of variation within each unit is fairly uniform between the seven test borings.

Tables

TABLE 1

HYDROSTRATIGRAPHIC UNITS
Du Pont Newport Site

Unit	Lithologic Appearance	Depth Range to top of Unit	Unit Range of Thickness
I	Shallow Zone. (Columbia Formation; Pleistocene) Clastics, yellow brown to orange sands and clays. Usually clayey near land surface, grading coarser with depth. This unit often contains a gray-black organic clay.	0	25-34
II	Semi-Confining Unit. (Top of Potomac Formation; Cretaceous) Marked by the first appearance of white-gray sand or reddish to orange sandy clays. Appears to be an effective semi-confining unit separating Unit I and Unit III_A.	25-34	23-40
III_A	Intermediate Zone. Clayey sand unit, consisting of clayey sands in the upper section grading to a more clayey unit with depth. Sands range from fine to medium grained with varying clay content. Color ranges from red to orange to yellow.	53-66	13-37
III_B	Semi-Confining Unit. This unit is very similar to III_A in color and shows interfingering of units except that the clay content increases significantly in the lower portion of this unit. The top of this unit is marked by a violet-red, manganese-stained clay. Appears to be an effective semi-confining unit separating Units III_A and IV.	75-93	10-39
IV	Deep Zone. Usually contains a white and light gray to orange medium clayey sand, up to ten feet in thickness overlying the bedrock. This unit may contain red dense clays and/or black organic-rich layers generally less than 18 inches thick.	90-118	15-30
V	Decomposed Bedrock. Olive green, friable, weathered schist and gneiss occasionally overlain by off-white clay. Probable low permeability; unit probably acts as base to active flow system.	110-140	10-40+

WM-44J

TABLE 2

DEPTH TO TOP OF HYDROSTRATIGRAPHIC UNITS*
BELOW LANDSURFACE (MSL)
Du Pont Newport Site

Hydrostratigraphic Unit	Test Boring (TB) 1	2	3	4	5	6	7
I Shallow Zone	LS (20.59)	LS (16.98)	LS (10.27)	LS (12.36)	LS (2.38)	LS (4.70)	LS (4.11)
II Semi-Confining Unit	34 (-13)	30 (-13)	26 (-16)	33 (-21)	30 (-28)	25 (-20)	27 (-23)
III_A Intermediate Zone	58 (-37)	60 (-43)	56 (-46)	56 (-44)	66 (-64)	65 (-60)	53 (-49)
III_B Semi-Confining Unit	75 (-54)	80 (-63)	93 (-83)	85 (-73)	92 (-90)	78 (-73)	80 (-76)
IV Deep Zone	114 (-93)	92 (-75)	118 (-108)	104 (-92)	110 (-108)	100 (-95)	90 (-86)
V Decomposed Bedrock	133 (-112)	115 (-98)	135 (-125)	125 (-113)	140 (-138)	115 (-110)	110 (-106)

* Based on geophysical logs and split-spoon samples analyses.

WM-44J

Figures

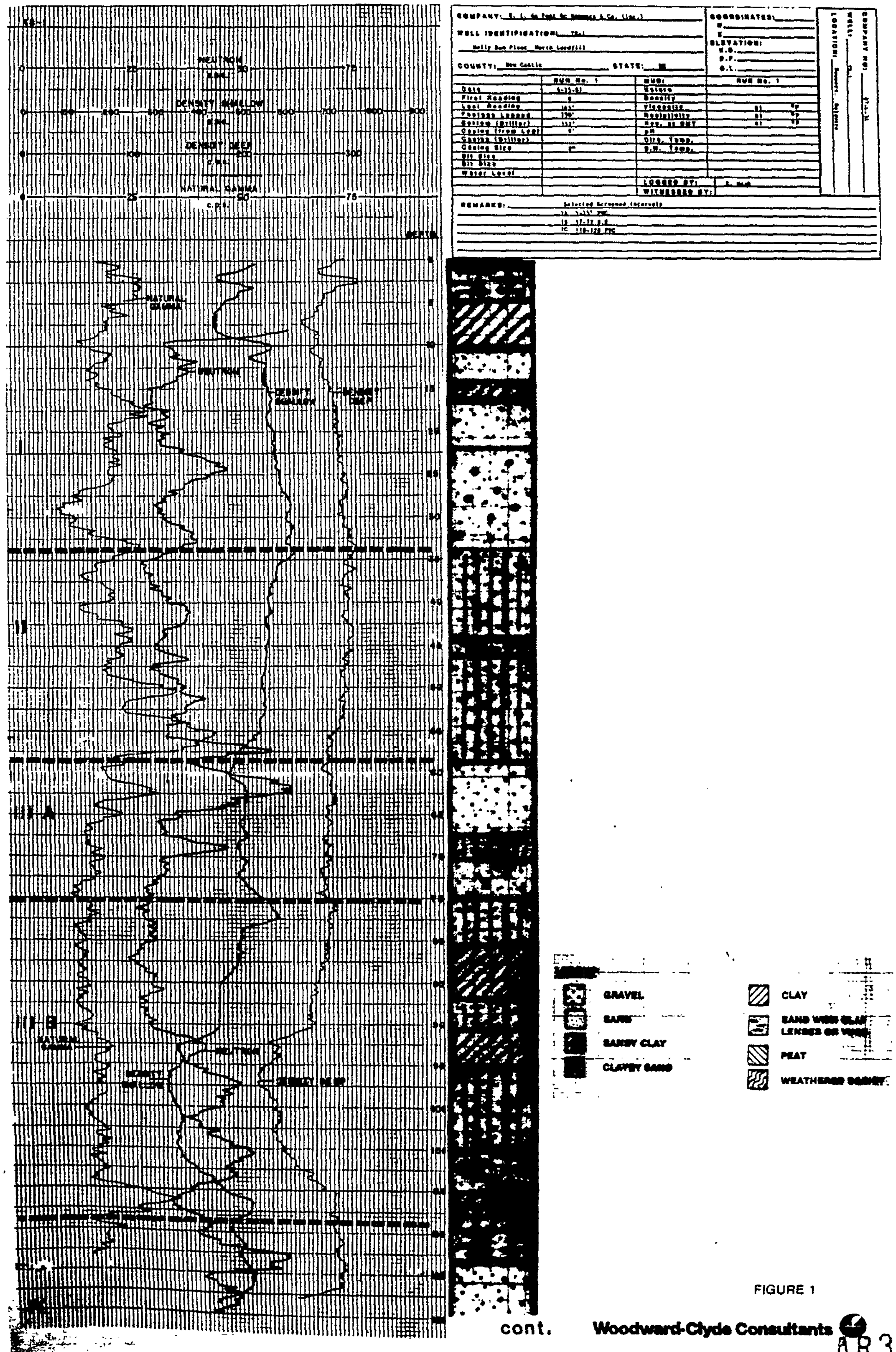

FIGURE 1

cont.

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AR301143

TB-1 cont.

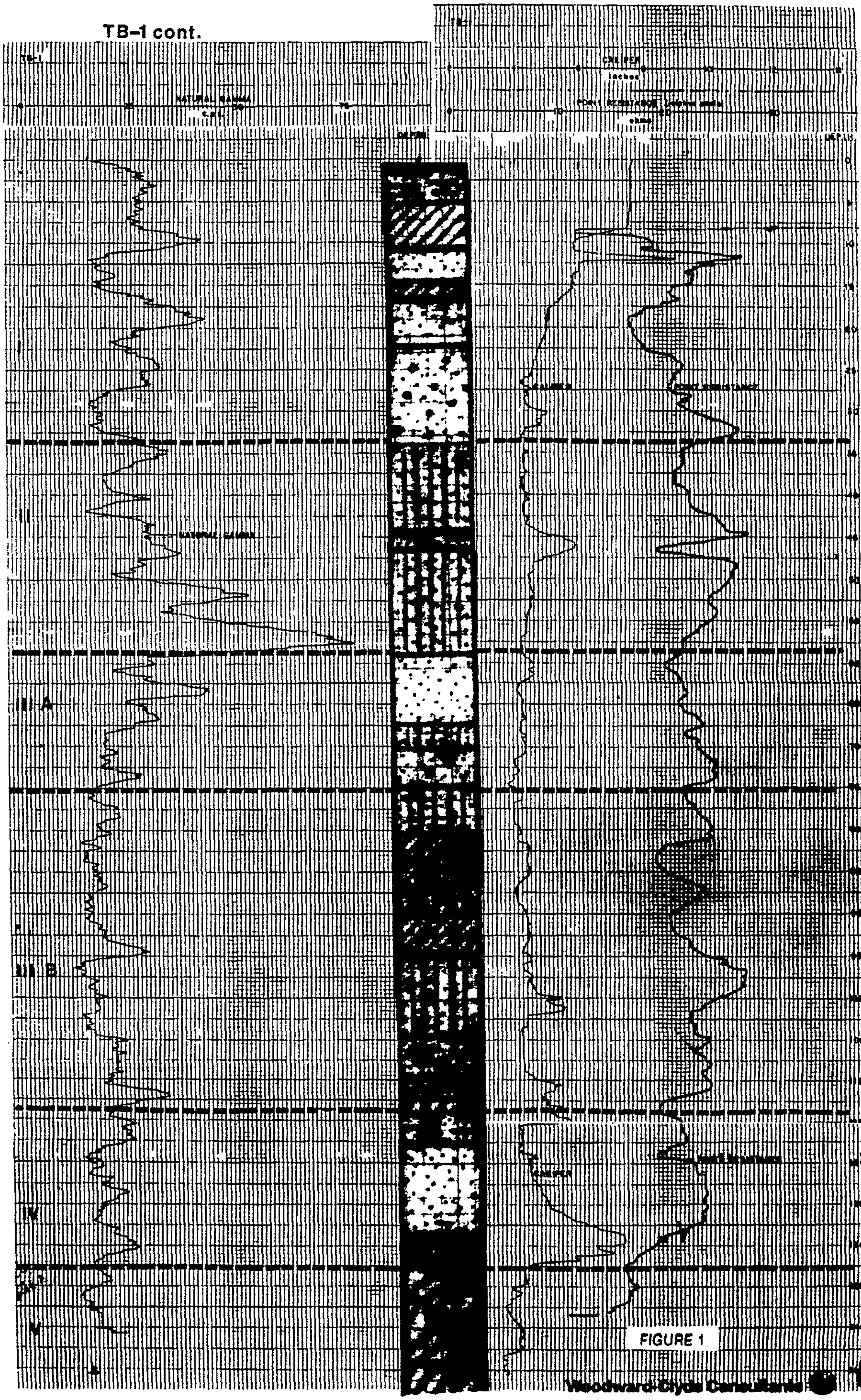

FIGURE 1

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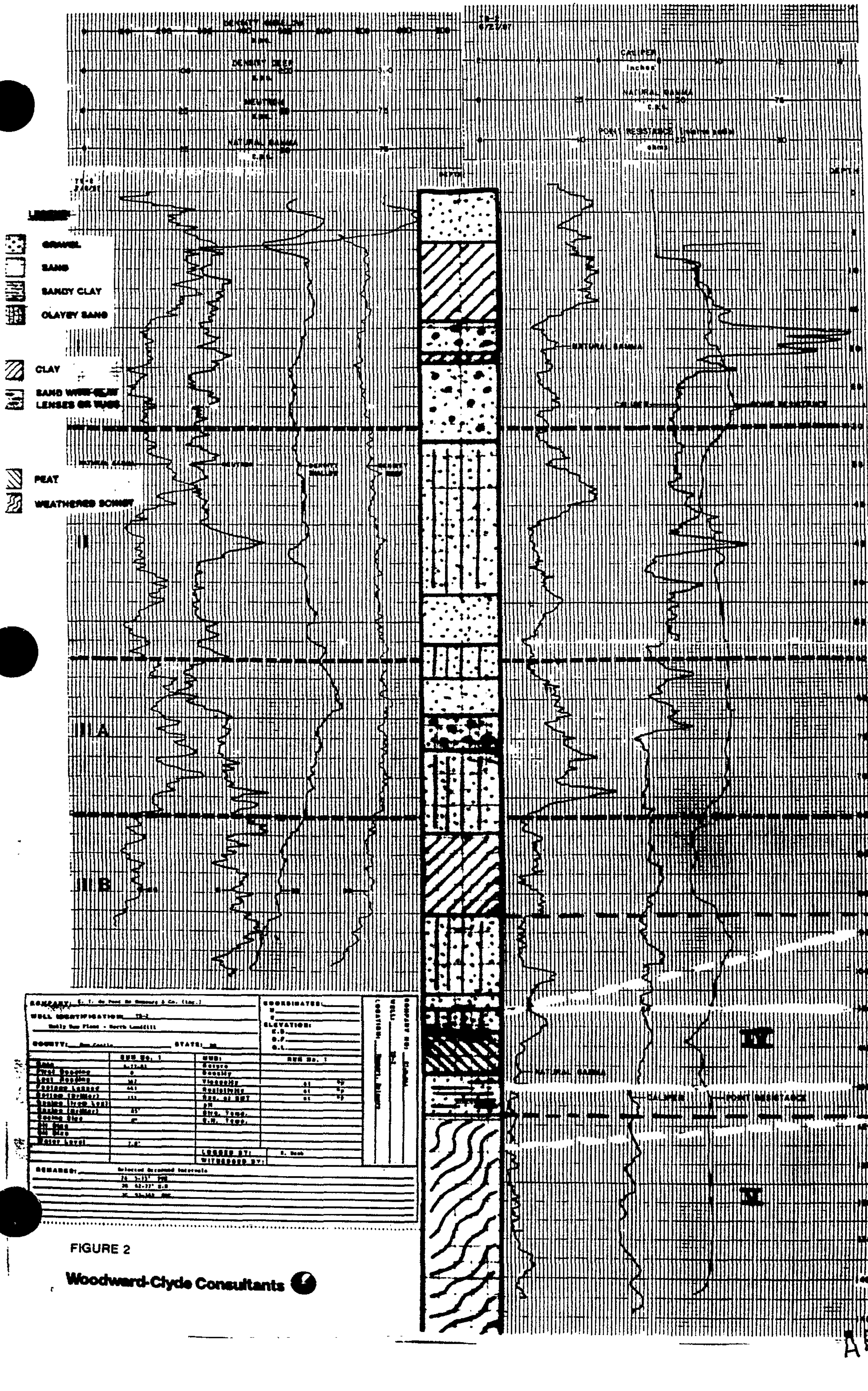

FIGURE 2

Woodward-Clyde Consultants

COMPANY: E. I. du Pont de Nemours & Co. (Inc.)		COORDINATES:	
WELL IDENTIFICATION: [illegible]		N	
[illegible]		E	
		ELEVATION:	
		K.B.	
		D.F.	
COUNTY: New Castle	STATE: [illegible]	G.L.	
	RUN No. 1	MUD:	RUN No. 1
Date	7-13-87	Nature	
Ft. of Reading	0	Density	
Last Reading	143'	Viscosity	[illegible]
Footage Logged	[illegible]	Resistivity	[illegible]
Bottom (Driller)	132	Res. at BHT	[illegible]
Casing (from Log)		pH	
Casing (Driller)	[illegible]	Circ. Temp.	
Casing Size	[illegible]	B.H. Temp.	
Bit Size			
Bit Size			
Water Level			
		LOGGED BY:	[illegible]
		WITNESSED BY:	

COMPANY NO: [illegible]
WELL: [illegible]
LOCATION: [illegible]

LEGEND

- GRAVEL
- SAND
- SANDY CLAY
- CLAYEY SAND
- CLAY
- SAND WITH CLAY LENSES OR VUGS
- PEAT
- WEATHERED SCHIST

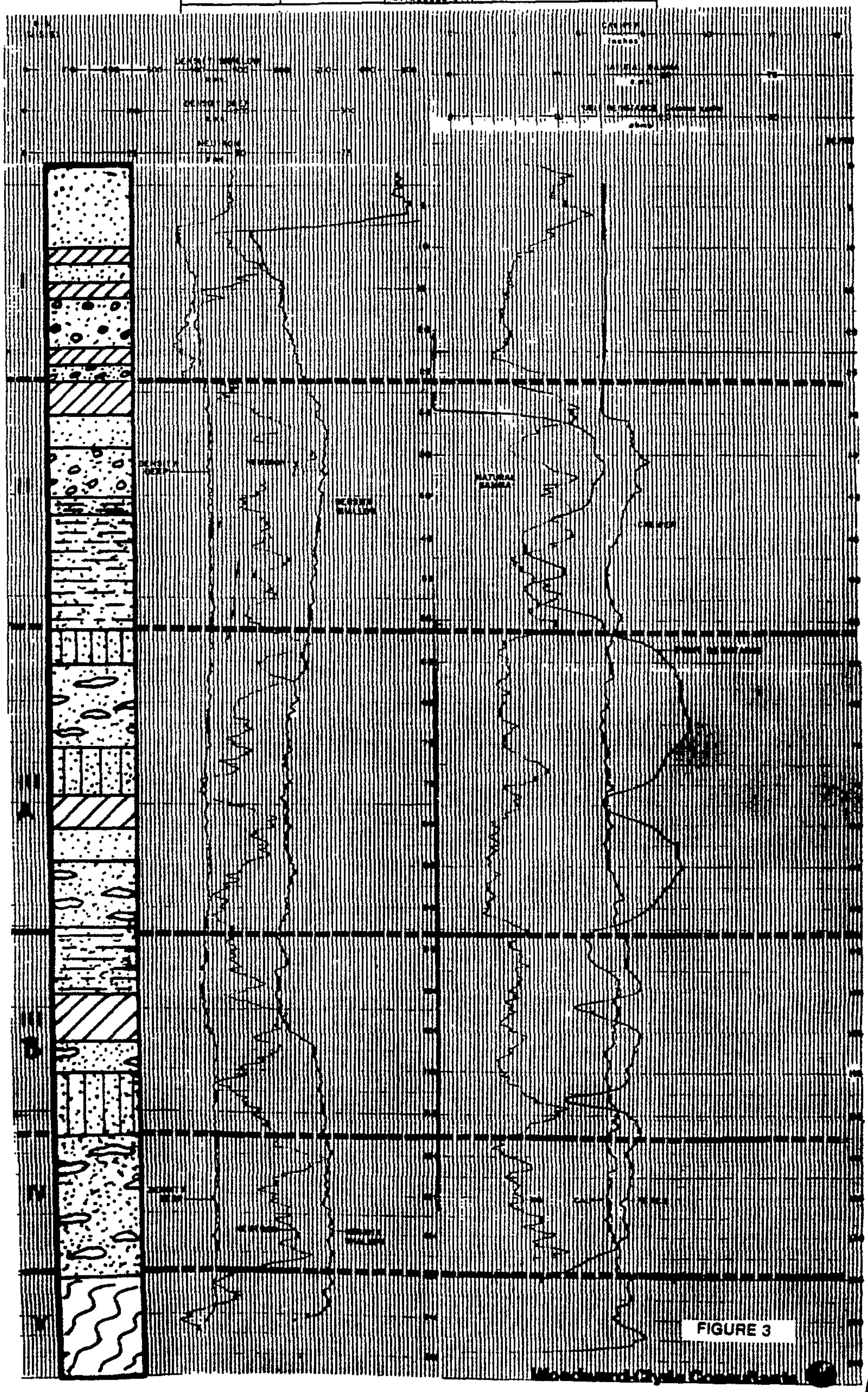

FIGURE 3

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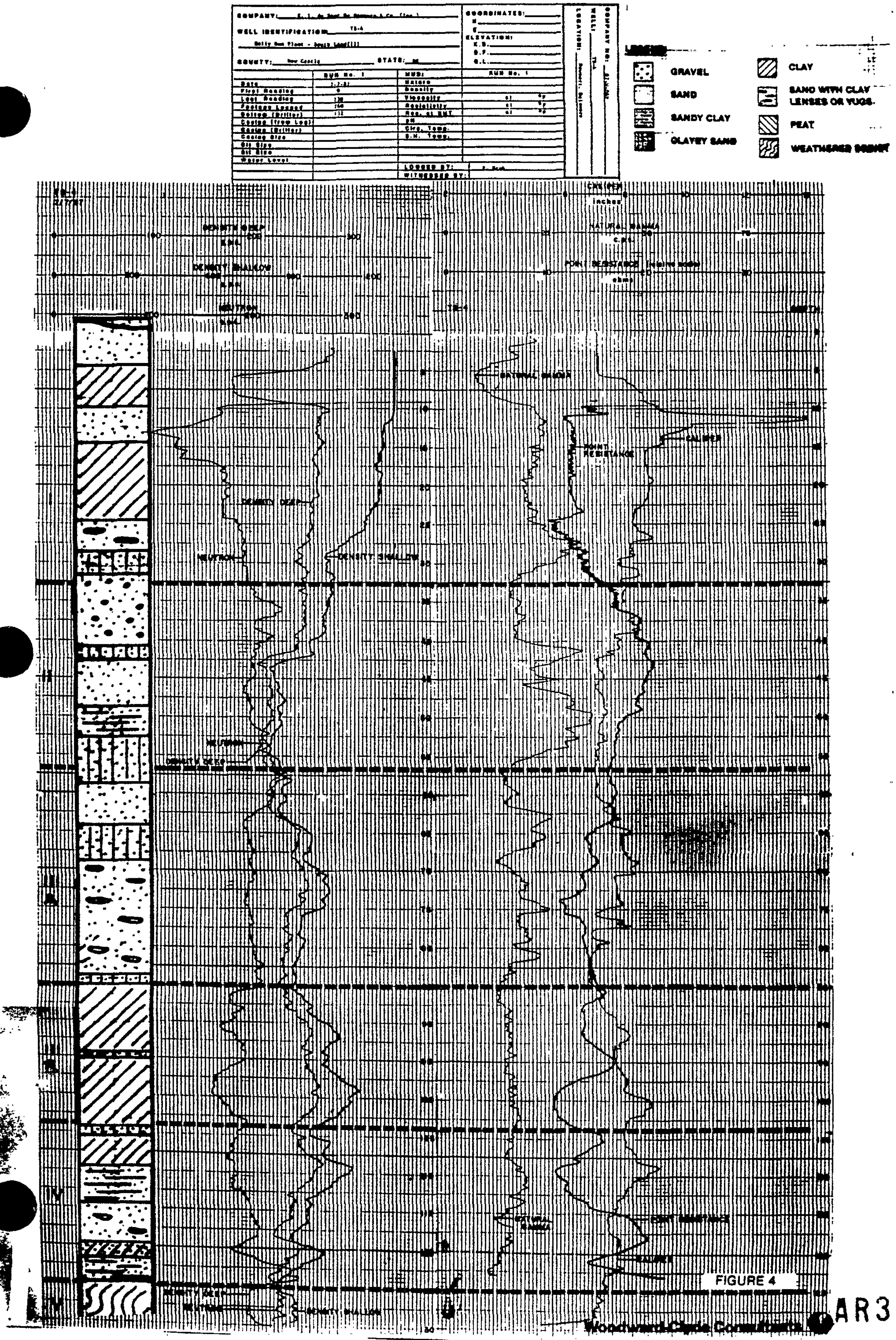

FIGURE 4

Woodward-Clyde Consultants

COMPANY:	E. I. du Pont De Nemours & Co. (Inc.)
WELL IDENTIFICATION:	TS 3
	Holly Run Plant - South Landfill
COUNTY:	New Castle
STATE:	DE
COORDINATES:	
N	
E	
ELEVATION:	
K.B.	
D.F.	
G.L.	

	RUN No. 1	MUD:	RUN No. 1
Date	7 11 87	Nature	
First Reading	0	Density	
Last Reading	148	Viscosity	at °F
Footage Logged	180	Resistivity	at °F
Bottom (Driller)	162'	Res. at BHT	at °F
Casing (from Log)		pH	
Casing (Driller)		Circ. Temp.	
Casing Size		B.H. Temp.	
Bit Size			
Bit Size			
Water Level			
		LOGGED BY:	[illegible]
		WITNESSED BY:	

COMPANY NO: 840-819
WELL: TS 3
LOCATION: [illegible]

REMARKS: Selected Screened Intervals
5A 2.5 - 12.5' PVC
5B 16 - 91' S.S.
5C 116.5 - 126.5 S.S.

LEGEND:

- GRAVEL
- SAND
- SANDY CLAY
- CLAYEY SAND
- CLAY
- SAND WITH CLAY LENSES OR VUGS
- PEAT
- WEATHERED SCHIST

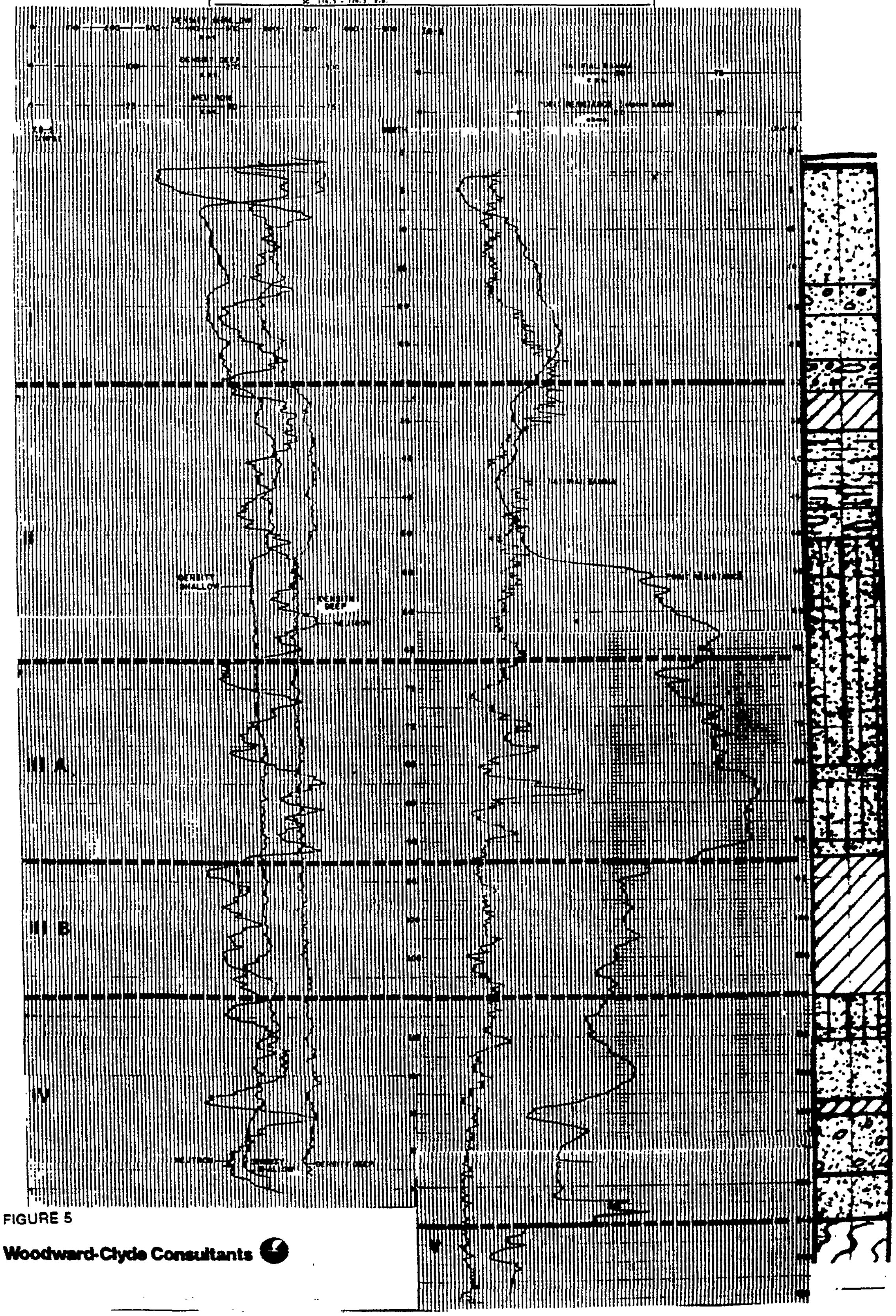

FIGURE 5

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AR301148

COMPANY: E. I. du Pont de Nemours & Co. (Inc.)

WELL IDENTIFICATION: TL-4

Dully Run Plant - South Landfill

COUNTY: New Castle STATE: DE

COORDINATES:
N
E
ELEVATION:
K.B.
D.F.
G.L.

COMPANY NO:
WELL: TL-4
LOCATION: Newport, Delaware

	RUN No. 1	MUD:	RUN No. 1
Date	7-1-87	Nature	
First Reading	0	Density	
Last Reading	150'	Viscosity	
Footage Logged	300'	Resistivity	
Bottom (Driller)	163'	Res. at BHT	
Casing (from Log)		pH	
Casing (Driller)		Circ. Temp.	
Casing Size		B.H. Temp.	
Bit Size			
Bit Size			
Water Level	18'		
		LOGGED BY:	
		WITNESSED BY:	

REMARKS: Selected Screened Intervals
AA 5-25' PVC
AB 67-77' S.S
AC 100.5-110.5' PVC

LEGEND

GRAVEL
SAND
SANDY CLAY
CLAYEY SAND
CLAY
SAND WITH CLAY LENSES OR VUGS.
PEAT
WEATHERED SCHIST

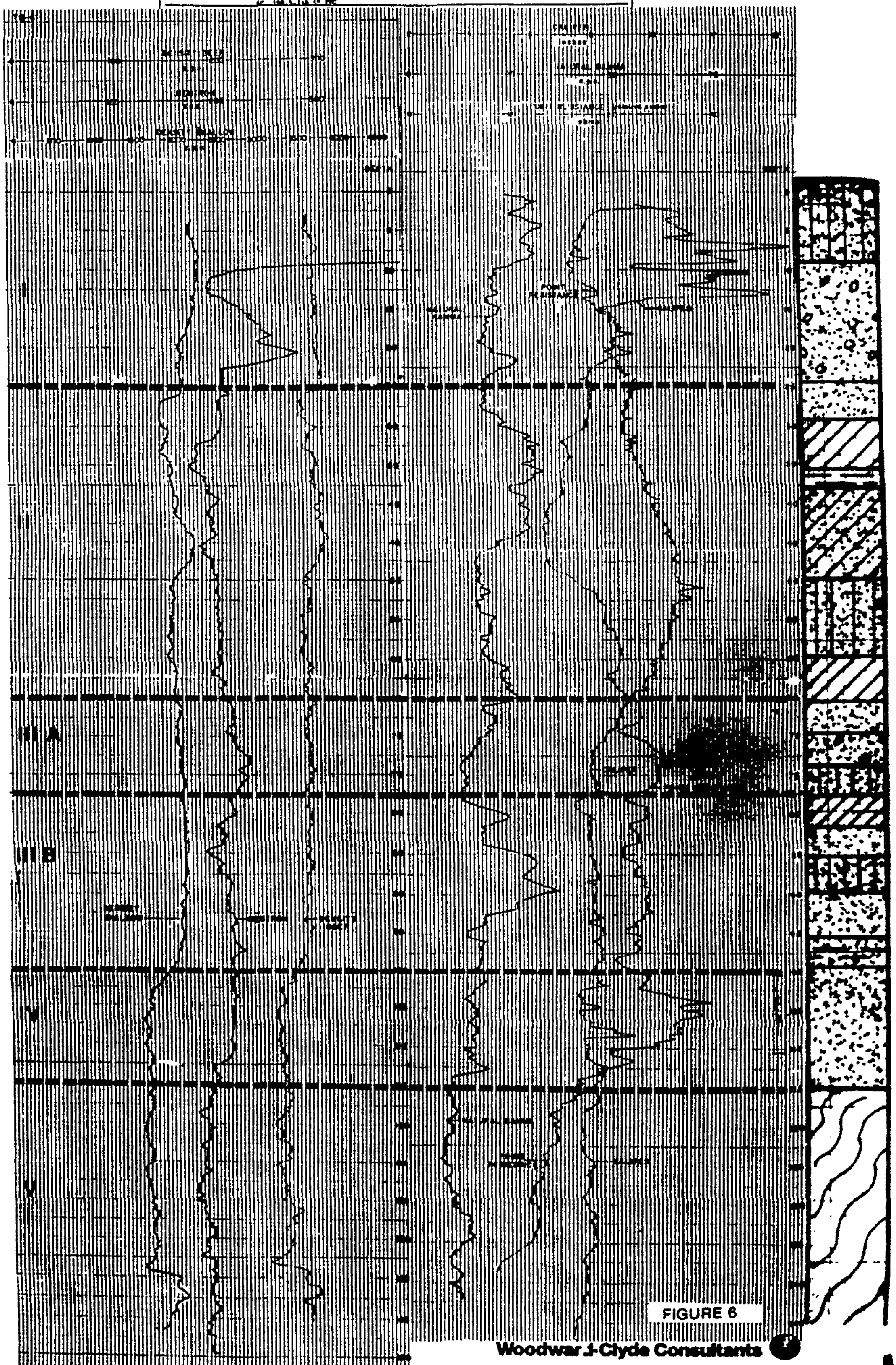

FIGURE 6

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AR301149

COMPANY: E. I. du Pont de Nemours & Co. Inc.

WELL IDENTIFICATION: TB-7

Belly Run Plume - South Landfill

COUNTY: New Castle STATE: Delaware

COORDINATES: N. E.

ELEVATION: K.B. G.F. G.L.

	RUN No. 1	MUD:	RUN No. 1
Date	7-16-81	Nature	
First Reading	0	Density	
Last Reading	113	Viscosity	at °F
Footage Logged	118	Resistivity	at °F
Bottom (Driller)	113	Res. at BHT	at °F
Casing (from Log)		pH	
Casing (Driller)	76'	Circ. Temp.	
Casing Size	4"	B.H. Temp.	
Bit Size			
Bit Size			
Water Level	10'		
		LOGGED BY:	T. Wenk
		WITNESSED BY:	

REMARKS: Selected Screened Intervals

7A 5-15' PVC

7B 61-78 S.S.

7C 96-109 S.S.

LOCATION: Newport, Delaware

WELL: TB-7

COMPANY NO.:

LEGEND

- GRAVEL
- SAND
- SANDY CLAY
- CLAYEY SAND
- CLAY
- SAND WITH CLAY LENSES OR VUGS
- PEAT
- WEATHERED SCHIST

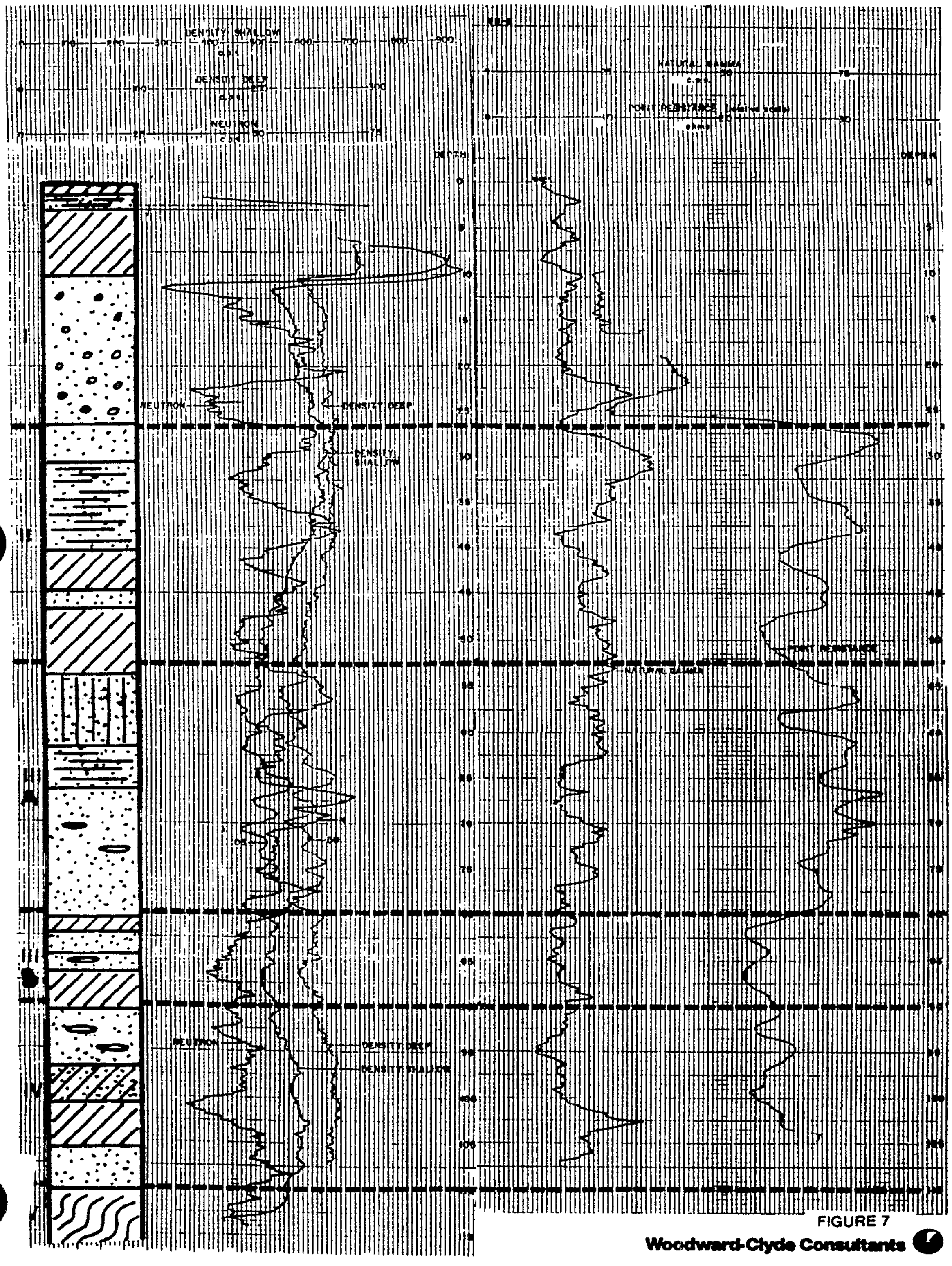

FIGURE 7

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AR301150

Appendix D

Aquifer Tests
DuPont Newport Site
Newport, Delaware

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1.0 DATA OBJECTIVES

As part of the remedial investigation of the Newport Site, two constant rate aquifer tests were conducted to estimate the groundwater transmissivity and storage characteristics of the lower Potomac Formation hydrostratigraphic Unit III_A. This report summarizes WCC's findings on aquifer tests conducted by separately pumping two monitoring wells located on the property of Du Pont. This report includes the data collected, interpretation of results, and the conclusions.

Previous investigations have indicated groundwater flow directions to be southerly toward the Christina River, which forms a hydrologic boundary for the shallow aquifers near the river. Data of the hydrogeologic investigation by WCC for the plant site indicate an upward gradient from the Potomac Formation (Units III_A and IV of this investigation) to the Shallow Zone (Unit I). This task evaluated the hydraulic characteristics of Unit III_A of the unconsolidated sediments beneath the North and South Disposal sites by separately pumping two monitoring wells and monitoring water levels in adjacent observation wells. A secondary goal was to estimate the hydraulic relationship between the shallow and deeper water-bearing units.

1.1 LIMITATIONS

Professional judgements presented herein are based partly on our evaluations of technical information gathered, partly on our understanding of Site conditions and history, and partly on our general experience. Our engineering work and judgements rendered meet current professional standards and reflect a degree of conservatism WCC deems proper for this project at this time.

Readers of this report should understand that the state of practice, particularly with respect to aquifer evaluation, is changing and evolving. While WCC performs in reasonable accordance with the standards set forth in effect at the time is services were performed, we recognize that those standards may subsequently change because of improvements in the state of the practice.

2.0 DESCRIPTION OF THE AQUIFER TESTS

2.1 GENERAL BACKGROUND AND PROCEDURES

Aquifer tests were conducted at the Newport Site by separately pumping monitoring wells MW-3B and MW-6B. Appendix D-1 lists a brief chronology of data logger and aquifer test events. The tests (Figure 1) and the work were conducted under the supervision of Dr. Roger Henning, task manager and hydrogeologist for WCC. Principal field observer was James Buczala (WCC). Mr. Buczala also set-up all equipment, calibrated the system and retrieved data on a routine basis. The On-Site Coordinator, Mr. James Goebel of Du Pont provided very valuable and conscientious support to the effort. Analysis and data reduction was done by Doug Rumbaugh, Steven Ennis, and Ellen Cool (all of WCC).

A NPDES discharge permit was applied for to allow for disposal of water recovered from pumping wells during the aquifer testing program. This permit was granted on August 4, 1987. Field work on this task began after permit approval and was completed on August 25, 1987.

Table 1 presents the pump-on time and date, pump-off time and date, amount of time recovery was observed, percent of recovery observed and weather conditions during the test, for each aquifer test run. Appendix E contains hydrographs of water level response in each well as a function of time (from August 1, 1987 to August 25, 1987).

The following procedures are relevant to each aquifer test:

1. Water levels in the wells were measured using Enviro-Labs data loggers with eight channels attached to downhole pressure transducers. Data was recorded at different time intervals depending when the pump was turned on or off.

2. A step-down test of several hours duration was used at each pumping well, to estimate appropriate pump rates for the aquifer tests. Prior to each part of the test, as a minimum, the pumping well was shut down and allowed to recover for 24 hours.

3. "Static" water levels were measured electronically in the pumping well, adjacent monitoring wells, and the Christina River prior to each pump-on time at 15-minute increments.

4. Data was logged on a standard time schedule that allowed for more frequent observations early in each drawdown or recovery leg and less frequent observations at later times when more stable conditions were expected to prevail. The standard schedule was:

Elapsed Time Period after Pump On or Off (minutes)	Time Interval Between Successive Logging Events	
	(Seconds)	(Minutes)
0 - 1	2	0.03
1 - 4	6	0.1
4 - 10	12	0.2
10 - 25	30	0.5
25 - 55	60	1.0
55 - 115	120	2.0
115 - 235	240	4.0
235 - end of test	- -	15.

5. Discharge rates were continuously monitored using a in-line flow meter with a dial display and totalizer, and occasionally checked by filling a 25 gallon drum while measuring time on a stopwatch. The discharge was maintained at a constant rate by adjusting a valve on the discharge line from the pump.

2.2 STEP-DRAWDOWN AQUIFER TESTS

A step-drawdown aquifer test was performed on both of the wells, MW-3B and MW-6B (Table 1). This type of test involves pumping the designated well at a series of constant flow rates (steps), with each subsequent flow rate greater than the previous rate.

Each step is run for a predetermined amount of time with dynamic water levels being measured at increasing time intervals. At the end of the last step, the pump was shut off and recovering water levels were measured and recorded over increasing time intervals.

The MW-3B test was run for four steps. The initial rate was 12.5 gpm for 1 hour 5 minutes (65 min). The next rate was 17.7 gpm for 30 minutes. The third rate was 27.3 gpm for 1 hour (60 minutes). The fourth rate was 30 gpm for 30 minutes.

The MW-6B test was run for four steps. The initial rate was 10 gpm for 45 minutes. The next rate was 20 gpm for 40 minutes. The third rate was 25 gpm for 35 minutes. The fourth rate was 33 gpm for 30 minutes.

The results of these tests were used to estimate specific capacities under different rates and safe constant pumping rates to be used during the constant rate aquifer tests. The specific capacity for MW-3B ranged from 0.53 gpm/ft at 12.5 gpm down to 0.46 gpm/ft at 30 gpm. It was decided that 20 gpm would be a safe constant pumping rate for the long term test on MW-3B.

The specific capacity for MW-6B ranged from 0.86 gpm/ft at 10 gpm down to 0.81 gpm/ft at 33 gpm. It was decided that 25 gpm would be a safe constant rate for the long term test on MW-6B.

2.3 CONSTANT-RATE AQUIFER TESTS

A constant-rate pumping test was performed on the same two wells, MW-3B (Table 2) and MW-6B (Table 3). The MW-3B was pumped at a constant discharge rate of 20 gallons per minute for a period of 100 hours. Once the pump was started, water level drawdown in the wells was measured according to the standard time schedule: At 6000 minutes the pump was shut down and recovering water levels were measured in all wells being monitored. These measurements were taken on a similar schedule to the drawdown phase, until the affected wells had reached 90 percent recovery, or for 8 hours after the pump had been shut off.

After recovery, MW-3B was re-started for a shorter duration, higher stress constant-rate test. The well was pumped at 30 gallons per minute for a period of 12 hours. Monitoring was the same as the initial test.

MW-6B was pumped at a constant discharge rate of 25 gallons per minute for a period of 73.5 hours. Wells were monitoring according to the standard time schedule. At 4410 minutes, the pump was shut off and recovery was begun.

Tables 2 and 3 present information relating to the constant-rate pumping tests run on production wells MW-3B and MW-6B, respectively.

3.0 TIDAL INFLUENCES

3.1 INTRODUCTION TO THE PROBLEM

Total measured head in a well is a composite of elevation head, pressure head, and velocity head. Because groundwater usually flows very slowly, the velocity head is a very small component of total head. Examination of well hydrographs in Appendix E shows that many of the wells show significant changes in head during periods of no pumping stress.

Tides in the Christina River were expected to have some impact on some wells so a transducer was installed in the river and a Stevens Recorder (Type F) was used at an elevation benchmark by the James Street bridge. The shapes of the hydrographs and the apparent relationship of time lag to distance from the river confirmed that tides are a major factor. If the results were not corrected to show the response without tidal influence, the simplistic analytical methods would not be accurate. Removal of all tidal influence was not possible, primarily because data was collected every 15 minutes rather than continuously during the representative tidal cycle, and other influences on groundwater level were also occurring. It is probable that atmospheric pressure effects, bank storage near the river, and groundwater recharge (infiltration to the water table) occurred during the period of record. Insufficient record length was available to evaluate the magnitude of their impact. The processed data shows that tidal influence correction appears to be the most important factor.

3.2 PROCEDURE FOR CORRECTING DATA

To remove the influence of tides from the data sets, WCC constructed a computer program to consistently treat each piece of data in exactly the same way. The procedure used relevant pre-pumping data for a specific well and tidal values for the same time period. It assumes that tide is the only trend during that time period and that the relationship fits the general form of:

$$x(t) = x'(t) + (T(t + \Delta t') - T) * f$$

where:

t	-	is a time
$x(t)$	-	is the measured head at time t
$x'(t)$	-	is the head without tidal effect at time t
$T(t)$	-	is tidal head at time t
$\Delta t'$	-	is the lag time
T	-	is mean tide head
f	-	is a scale factor.

The correction procedure was to use generalized matrix inversion with ridge regression to solve many equations with four unknowns. The many equations are generated by having one equation for each data point set at a same time. There are actually only three unknowns $x'(t)$, $\Delta t'$, and f. T (meantide), can be evaluated independently of the algorithm and serves as a check on the optimization routine.

After the tidal effect is calculated, the tidal differences are subtracted from the data using the following equation:

$$x'(t) = x(t) - (T(t + \Delta t') - T) * f$$

This assumes that values obtained from the tidal baseline cycle can be extrapolated throughout the entire data set, namely August, 1, 1987 to August 25, 1987. It also assumes that the stressed system does not react differently than the unstressed systems.

Examination of the corrected data sets for the times during the aquifer test show that there are some minor influences that still remain, probably as a result of inaccuracies in adjusting lag on a data set incrementized on a 15 minute basis. The residual errors appear to be small enough to be hidden in the accuracy of the analytical solutions for hydraulic properties. Curve matching is most controlled by the early times where data was collected on a 2 to 240 second (0.03 to 4 minute) basis during the first 235 minutes of each drawdown and recovery log. This means that inaccuracies in log calculation when data is logged every 15 minutes should have a negligible effect on calculated hydraulic properties.

4.0 ANALYSIS OF AQUIFER TEST DATA

4.1 INTRODUCTION

The analyses of constant-rate and step-drawdown aquifer tests can yield essential information for the estimation of aquifer hydraulic characteristics, the extent of the radius of influence of the pumping well, and well capacity. This report deals primarily with the aquifer hydraulic characteristics.

The analytical methods used to evaluate the aquifer test data assume that the following conditions apply:

- The aquifer has a seemingly infinite areal extent.
- The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the pumping test.
- Prior to pumping the piezometric surface is nearly horizontal over the area influenced by the pumping test.
- The pumped well penetrates the entire aquifer.

is semi-confined and may show leakage or demonstrate the effects of delayed yield, this method is considered most reliable for the analyses.

An example of a graph prepared to utilize this method is presented as Figures 2 and 3; where the drawdown versus time plot is matched with the appropriate Prickett type curve in order to select a match point. The match point coordinates, s, 1/Ua, W (Ua, r/b) and t are substituted into the following equations to determine the coefficients of transmissivity, T and storage, S.

$$T = \frac{114.6\ Q\ W\ (U_a, \frac{r}{b})}{s} \qquad S = T\ \frac{t}{r^2}\ \frac{U_a}{2693}$$

where:

	s	=	drawdown in feet
	r	=	distance from pumped well to observation well, in feet
	Q	=	discharge rate, in gallons per minute
	t	=	time after pumping started, in minutes

The following methods are not as appropriate as the Prickett method, but can add valuable insight into how the aquifer is responding to the pumping. Curve-matching like Prickett can be quite subjective and prone to operator interpretation. Straight-line plots may not be as accurate, but are more consistent and less apt to be influenced by operator bias. The straight forward application of a uniform methodology to all results gives a good idea of variations as a result of aquifer response rather than operator interpretation of the best curve fit.

In Jacob's method of interpreting aquifer characteristics using straight-line interpretation, corrected drawdown and uncorrected drawdown are plotted against the log of the time (since pumping started) as illustrated in Figures 4 and 5, values for T and S were then calculated using the following equations:

$$T = \frac{264Q}{\Delta s} \qquad S = \frac{0.3\ T\ t_0}{r^2}$$

where: Q = discharge rate, in gallons per minute

Δs = change in drawdown per logarithmic cycle

T = transmissivity, in gallons per day per foot

t_o = is the zero drawdown time intercept, in days

r = distance from pumped well to observation well, in feet

S = coefficient of storage

Figure 16 is an example of Jacob's recovery method, in which recovering water

where:

Q	=	discharge rate, in gallons per minute
Δs	=	change in drawdown per logarithmic cycle
T	=	transmissivity, in gallons per day per foot
t_o	=	is the zero drawdown time intercept, in days
r	=	distance from pumped well to observation well, in feet
S	=	coefficient of storage

Figure 16 is an example of Jacob's recovery method, in which recovering water levels are plotted against the log of t/t', where t is the time since pumping started and t' is the time since pumping stopped. Transmissivity was then calculated using the following expression (parameters derived as above).

$$T = \frac{264Q}{\Delta s}$$

4.3 DISTANCE-DRAWDOWN ANALYSIS

Distance-drawdown evaluation requires that you have two, preferably three, points at different distances from the pumping well finished in the same aquifer. Distance-drawdown data were plotted,but there was not enough response (considering tides) to warrant their use for aquifer analysis. As can be seen on Table 2 (test at MW-3B) and considering that the pumped well data is unreliable because of well loss, MW-1B and MW-2B are about the same distance and have the same drawdown. The only other well in the Intermediate Zone is WW-13 which is farther and has only slightly less drawdown.

For the MW-6B test, MW-5B and MW-7B are about the same distance, but MW-5B showed only 0.5 feet more drawdown.

5.0 RESULTS OF ANALYSES

5.1 AQUIFER TEST RESULTS

Transmissivity (T) and Storativity (S) of Zone III_A

The Prickett-Boulton method yields the most reliable values for T and S for the Intermediate Zone at the Newport Site. Computed values for T using this method range from 2000 - 4000 gallons per day per foot (gpd/ft). The T values obtained from the other method ranged from 1700 - 7500 gpd/ft for values which represent aquifer characteristics before boundaries. Thus, transmissivity in the areas of MW-3B pumped are estimated to range from 2000 - 4000 gpd/ft with a mean of 3000 gpd/ft. The first test was begun as the tide was rising and the estimated value of T may be lower than true T. The second test occurred during a falling tide and estimate value of T may be higher than true T.

In Jacob's drawdown method, late values calculated for transmissivity are consistently higher than those calculated from early drawdown data.

Well losses in MW-3B and MW-6B due to the impact of tides probably gave T values that were lower than actual because the drawdowns appeared to be greater than actual. This increase in transmissivity could also be attributed to a combination of any of the following: effects of leakage from confining layers; increases in the storability of the aquifer away from the well; or the interception of a hydraulic recharge zone.

The storativity values believed to be most reliable are those derived by the Prickett-Boulton method. The early data were used to estimate storativity of 2×10^{-4} to 4×10^{-4}. These values are associated with the volume of water instantaneously released from storage and are not associated with long term pumping conditions. These values are also consistent with the semi-confined conditions of the Intermediate Zone at the Newport Site.

Figure 18 shows the relationship of specific capacity after one day to T and S. Both pumping wells show that the T and S values from aquifer testing are consistent with the specific capacities calculated from the step-drawdown tests.

To estimate a range of groundwater flow velocities, some assumptions about thickness of the aquifer, porosity of the aquifer and effective gradients must be made. The Intermediate Zone (Unit III_A) is estimated to be 13 to 37 feet thick. In the area of TB-3, there is about 35 feet of effective aquifer in this zone. In the area of TB-6, Unit III_A is about 20 feet thick. If an estimated transmissivity at MW-3B of about 3000 gpd/ft and at MW-6B is about 4000 gpd/ft is used, then the hydraulic conductivity at MW-3B is about 85 gpd/ft^2 and at MW-6B is about 200 gpd/ft^2. The porosity is about 20 percent or 0.2, on the average.

The formula to calculate velocity is derived from the Darcy equation:

$$V = \frac{Ki}{n\ (7.48)}$$

V	=	velocity, in ft/day
K	=	hydraulic conductivity, in gpd/ft^2
i	=	gradient (ft/ft)
n	=	porosity (ratio)
(7.48)	=	converts gallons to cubic feet

At MW-3B (Low Tide)

$$V = \frac{85\ (2/320)}{.2\ (7.48)}$$

$$V = 0.36 \text{ ft/day}$$

At MW-6B (Low Tide)

$$V = \frac{200\ (1/800)}{.2\ (7.48)}$$

$$V = 0.17 \text{ ft/day}$$

At MW-3B (High Tide)

$$V = \frac{85\ (1/280)}{0.2\ (7.48)}$$

$$V = 0.20 \text{ ft/day}$$

At MW-6B (High Tide)

$$V = \frac{200\ (2/500)}{.2\ (7.48)}$$

$$V = 0.54 \text{ ft/day}$$

Based on these assumptions, the estimated groundwater flow velocities in the Intermediate Zone (Unit III_A) are about 0.2 to 0.4 ft/day north of the Christina River and about 0.2 to 0.6 ft/day south of the Christina River. Due to the heterogeneity of the water-bearing zones, these estimated velocities can only be applied in a general sense to the hydrostratigraphic unit as a whole entity, and not to any individual sand lens.

5.2 SHALLOW ZONE RESPONSE

Very little observable response was noted in monitoring wells screened in the water Shallow Zone (Unit I) above the pumped zone (III_A) as exemplified by wells MW-6A, MW-1A, MW-3A (see hydrographs in Appendix E). These wells also showed little response from tidal effects.

6.0 CONCLUSIONS

The conclusions that can be drawn from reviewing the aquifer test are listed below.

1. The estimated transmissivity of the Intermediate Zone (Unit III_A) in the vicinity of MW-3B is about 3000 gpd/ft. The estimated transmissivity near MW-1B and MW-2B is probably higher, in the order of 4000 to 6000 gpd/ft. The transmissivity near MW-6B is estimated to be about 3000 - 4000 gpd/ft.

2. Estimates of aquifer characteristics utilizing different analytical methods differed slightly. Thus, even if the actual subsurface conditions varied from those assumed, the estimates are reasonable approximations of actual subsurface hydraulic conditions.

3. The lack of apparent impact that the pumping had on the water levels of the Shallow Zone wells can be attributed to:

   a. delayed yield caused by limited vertical permeability of the semi-confining Unit II;

   b. high transmissivity in the Shallow Zone quickly replacing water lost vertically to the semi-confining unit; and

   c. the horizontal conductivity of the sediments in Intermediate Zone (Unit III_A) may be much higher than the vertical conductivity of the semi-confining Unit II, allowing water from adjacent areas to flow to the well in preference to water directly above in the unconfined Shallow Zone.

   d. Given the difference in heads between Units III_A and I, it is most likely that Unit II acts as a low permeability Zone.

4. Tides caused major perturbations in water levels measured in wells during the tests, but comparisons with the hydrographs with and without correction showed that the methods were valid.

5. The storage coefficient for the Intermediate Zone is consistent with a leaky semi-confined aquifer system.

6. Results may be interpreted to indicate that Units III_A and IV are interconnected because they show similar response. It may be that the lower Potomac Formation sand units respond as one hydrostratigraphic unit even through the boring logs showed considerable fine grained beds separating the two water-bearing zones.

7. The Columbia Formation appears to be hydraulically separated from the lower Potomac Formation sand units by the Potomac Formation clay/silts aquitard.

8. Evaluation of vertical leakance by analytical methods was considered inappropriate because tidal masking and/or cross-connection of Units III_A and IV did not allow determination of release from storage or movement across the aquitard. Recovery curves did suggest some recharge effects between Units III_A and IV.

9. Groundwater flow velocities in the Intermediate Zone (Unit III_A) are estimated to range from about 0.2 to 0.4 ft/day on the north side of the Christina River and about 0.2 to 0.6 ft/day on the south side of the Christina River.

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Tables

TABLE 1

AQUIFER TEST INFORMATION

Well No.	Type of Aquifer Test	Pump On Time/ Date	Pump Off Time/ Date	Duration (min)	Weather Conditions During Test
MW-3B	Step Drawdown	18:35 8/03/87	21:55 8/03/87	200	Warm, damp
MW-3B	Constant Rate	7:30 8/06/87	11:30 8/10/87	6000	2.8" Rain, night before, hot, humid during, 0.3" rain near end.
MW-3B	Constant Rate	7:30 8/11/87	19:30 8/11/87	720	Hot, humid
MW-6B	Step Drawdown	19:20 8/19/87	21:55 8/19/87	155	Warm, damp
MW-6B	Constant Rate	9:00 8/21/87	10:30 8/24/87	4410	Hot, humid some rain

WM-44J

Table 2

MW-3B CONSTANT-RATE AQUIFER TESTS

Representative Wells Monitored During Test	Distance From MW-3B (ft)	Observed Drawdown (ft)	Zone of Screened Interval
MW-1A	N/A	0	I
MW-1B	750	1.6	III_A
MW-1C	N/A	1.8	III_B
MW-2A	N/A	0	I
MW-2B	760	1.6	III_A
MW-2C	N/A	1.7	III_B
MW-3A	N/A	0	I
MW-3B	0	40	III_A
MW-3C	N/A	4	III_B
DM-6	270	2	III_A
WW-13	950	1.4	III_B
SM-2	600 (N/A)	0	I

N/A - Not Applicable (in different zone)

WM-44J

TABLE 3

MW-6B CONSTANT-RATE AQUIFER TESTS

Representative Wells Monitored During Test	Distance From MW-3B (ft)	Observed Drawdown (ft)	Zone of Screened Interval
MW-6A	N/A	0	I
MW-6B	0	38	III_A
MW-6C	N/A	6	III_B
MW-5A	N/A	0	I
MW-5B	810	2.5	III_A
MW-5C	N/A	1.5	III_B
MW-7A	N/A	0	I
MW-7B	820	2	III_A
MW-7C	N/A	1.5	III_B
MW-11	280 (N/A)	0	I
MW-13	280 (N/A)	0	I
DML-7	1300	0.5	III_B
DMU-7	1260 (N/A)	0	II

N/A - Not Applicable (in different zone)

WM-44J

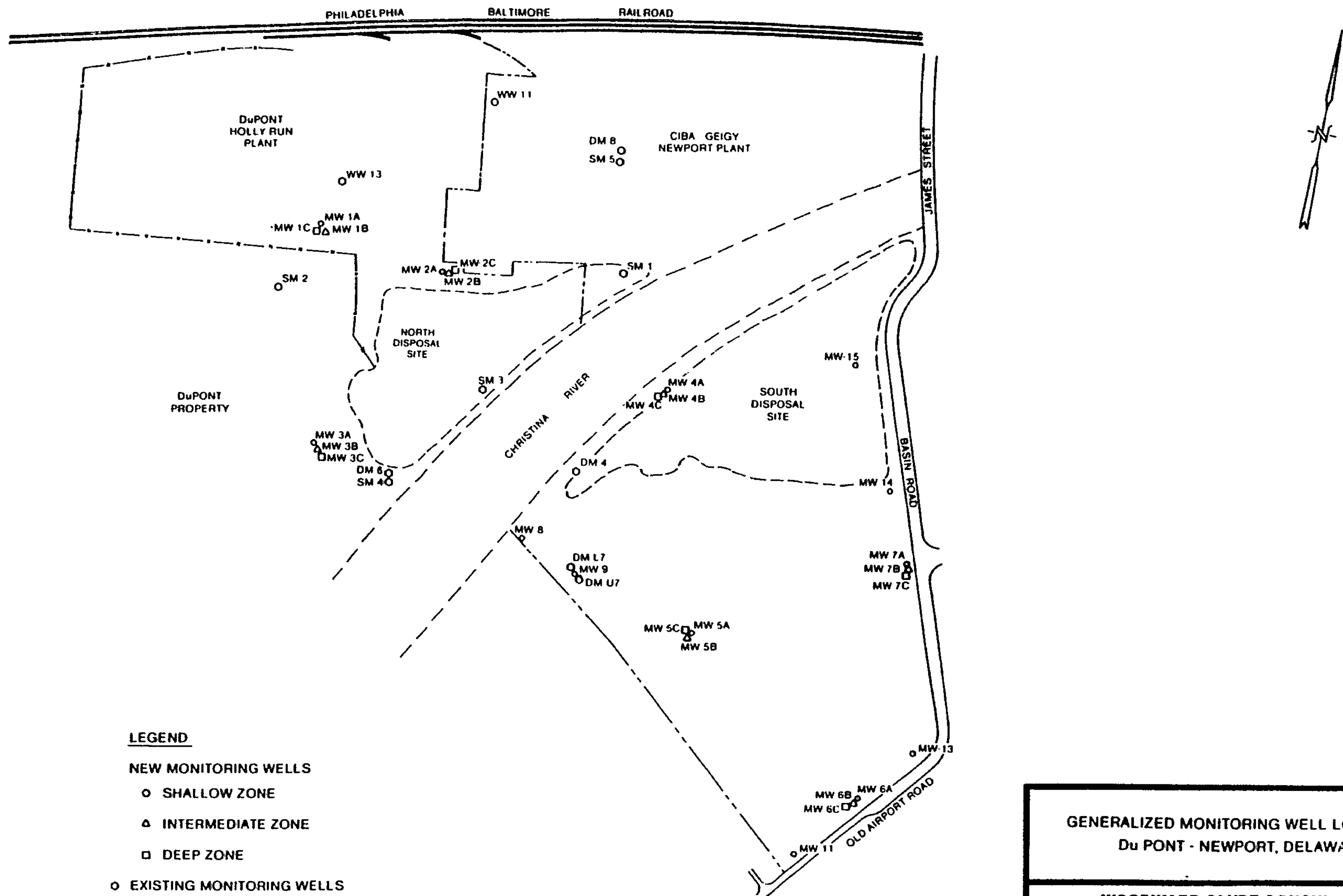
TABLE 4

SURVEYED MONITORING WELL ELEVATIONS
(MSL, Feet)

Well No.	Ground Surface	Top of Steel Casing	Top of PVC Casing
MW-1A	20.46	23.05	22.72
MW-1B	20.36	23.12	22.74
MW-1C	20.59	23.04	22.74
MW-2A	16.43	19.39	18.76
MW-2B	16.35	18.94	18.76
MW-2C	16.98	19.49	19.07
MW-3A	11.45	14.21	13.84
MW-3B	10.98	13.97	13.64
MW-3C	10.27	13.09	12.78
MW-4A	13.32	16.00	15.70
MW-4B	12.69	15.24	14.94
MW-4C	12.36	15.02	14.76
MW-5A	2.75	5.82	5.58
MW-5B	2.17	5.24	4.98
MW-5C	2.38	5.34	5.13
MW-6A	4.39	7.71	7.33
MW-6B	5.11	7.77	7.48
MW-6C	4.70	7.67	7.38
MW-7A	5.14	8.33	7.96
MW-7B	5.17	8.12	7.83
MW-7C	4.11	6.97	6.68
MW-8	4.80	7.36	7.10
MW-9	9.21	12.12	11.78
MW-11	6.34	9.10	8.75
MW-13	4.10	6.85	6.49
MW-14	7.69	10.84	10.52
MW-15	10.73	13.50	13.16
SM-1	22.78	none	- -
SM-2	14.62	18.70	18.65
SM-3	25.92	none	27.87
SM-4	3.80	6.90	6.80
SM-5	18.60*		
DM-4	8.13	10.93	10.94
DM-6	4.02	7.40	10.24**
DMU-7	9.91	11.87	11.52
DML-7	9.94	11.78	11.72
DM-8	18.0*		
WW-11	16.34	18.98	- -
WW-13	- -	24.35	- -
James/Water Street Tidal Gauge	5.20 Benchmark		

* Original Du Pont elevations, only.
** Originally, 7.30; extended up 8/87

Figures

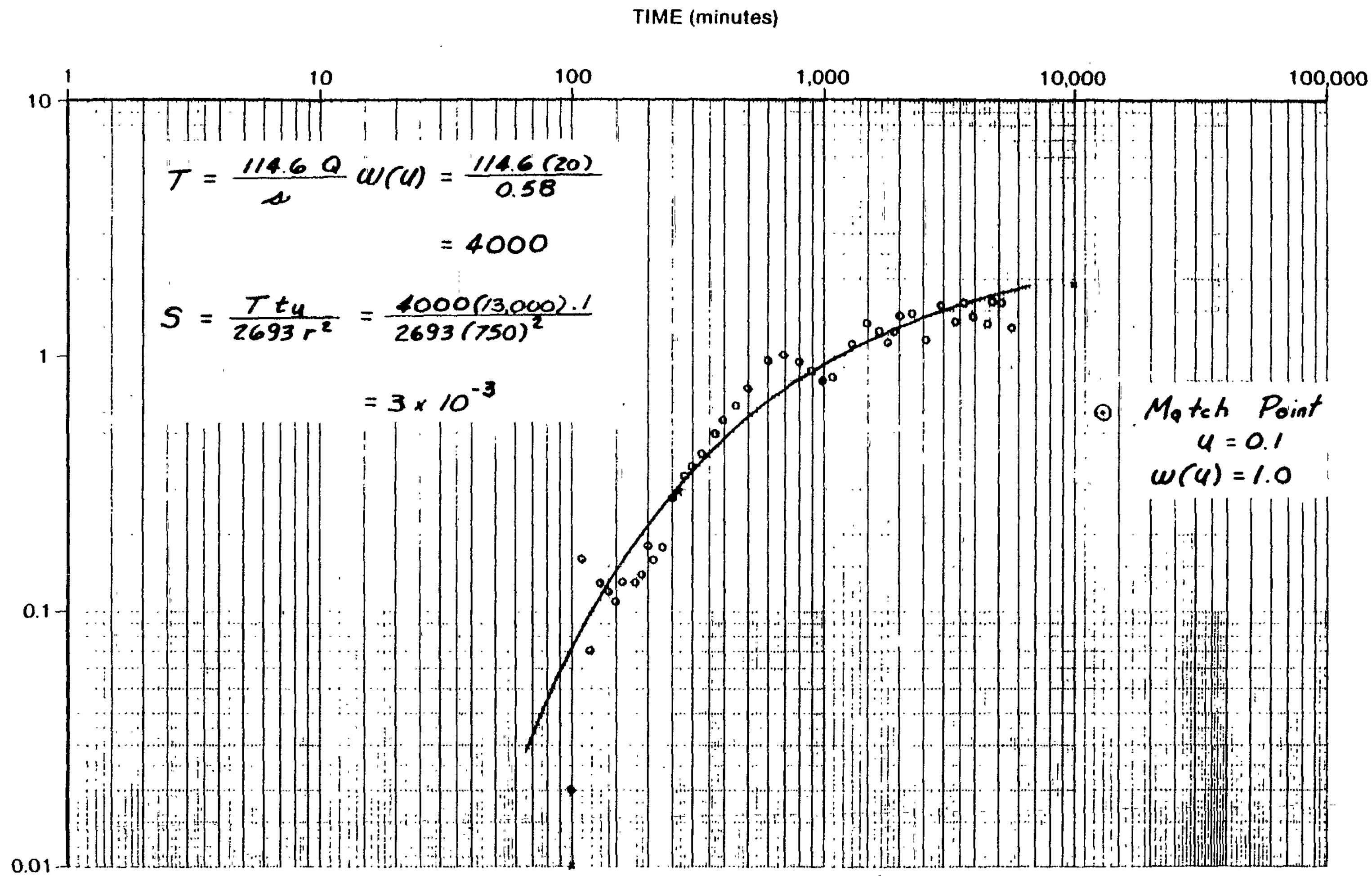


GENERALIZED MONITORING WELL LOCATIONS
Du PONT - NEWPORT, DELAWARE

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

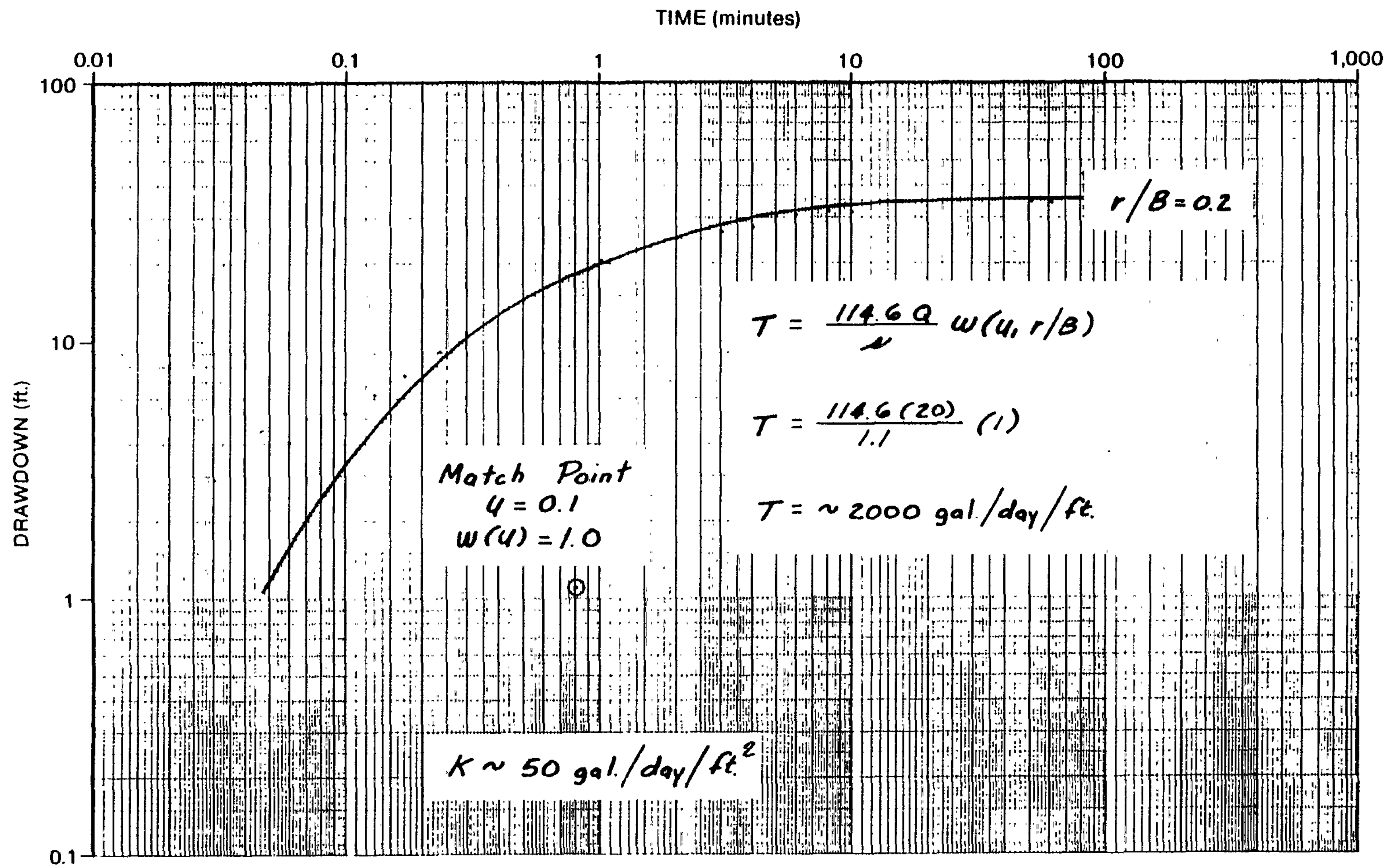
Drawn by T P	SCALE IN FEET 0 — 400	Date 9/16/87	
Checked by R T G		Job 88C2076-2	

FIGURE 1



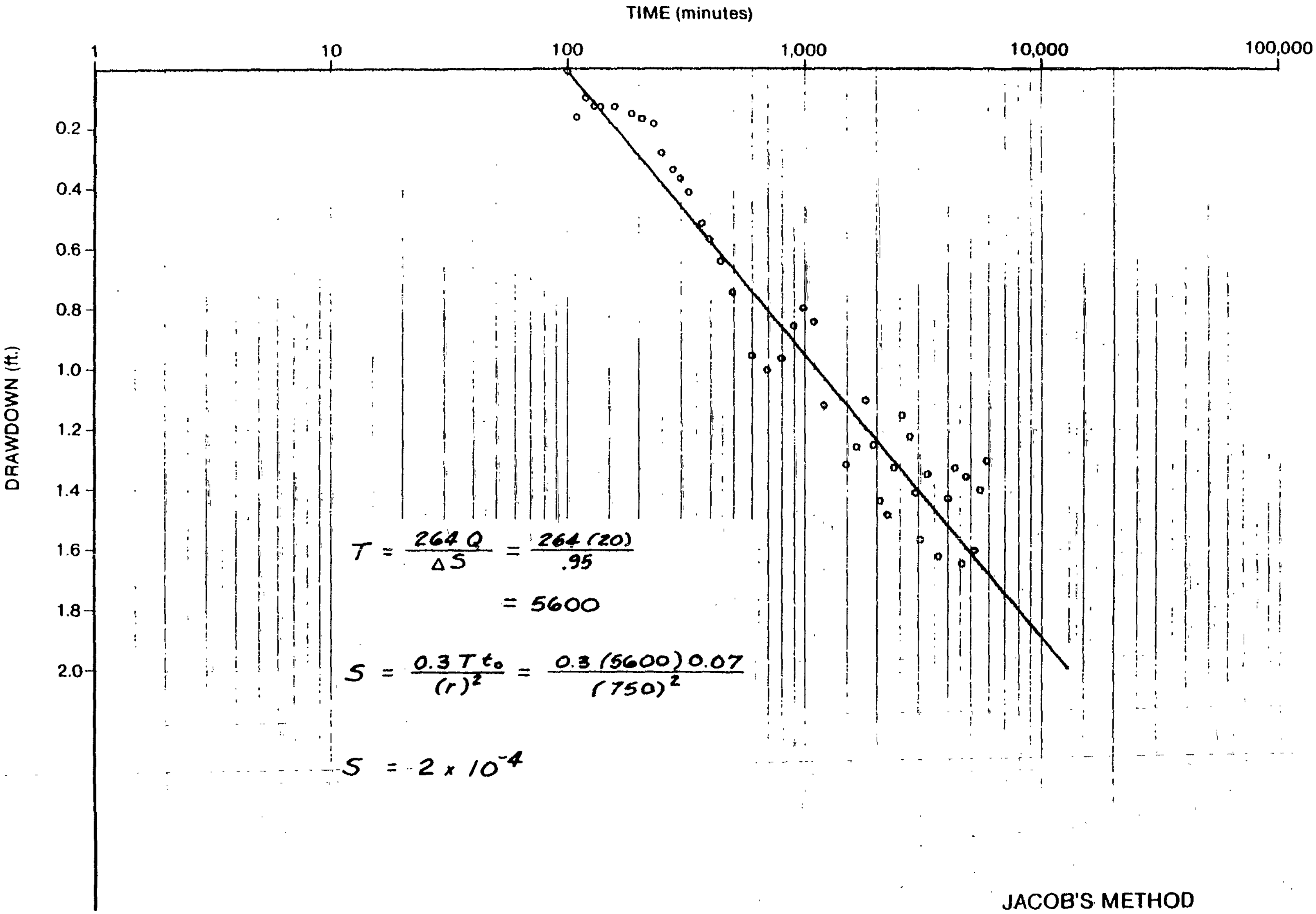
PRICKET - BOULTON METHOD
1st Test, MW-2B

FIGURE 2



PRICKET - BOULTON METHOD
1st TEST, MW-3B

FIGURE 3



$$T = \frac{264\,Q}{\Delta S} = \frac{264\,(20)}{.95}$$

$$= 5600$$

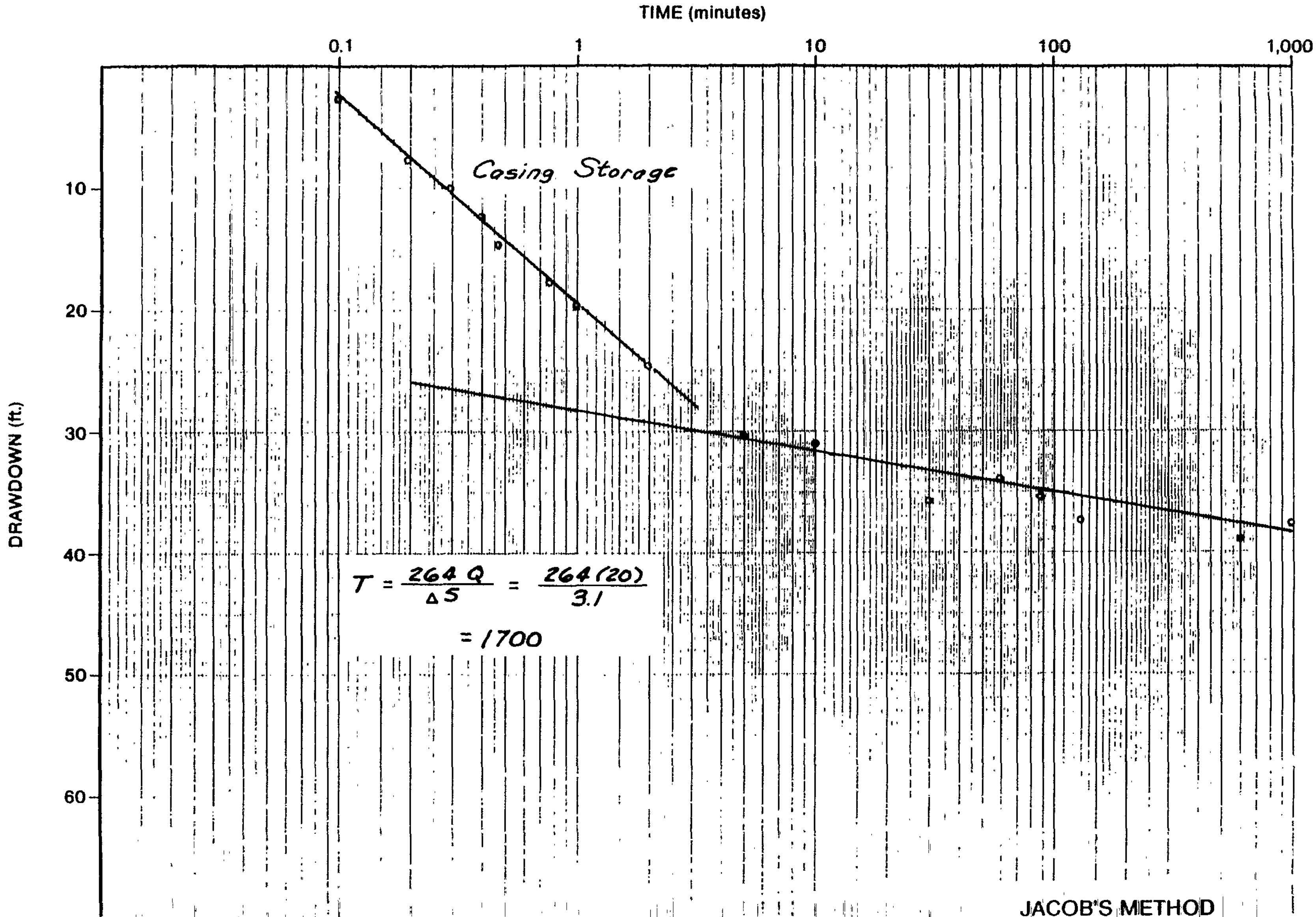
$$S = \frac{0.3\,T\,t_0}{(r)^2} = \frac{0.3\,(5600)\,0.07}{(750)^2}$$

$$S = 2 \times 10^{-4}$$

JACOB'S METHOD
1st TEST, MW-2B

FIGURE 4

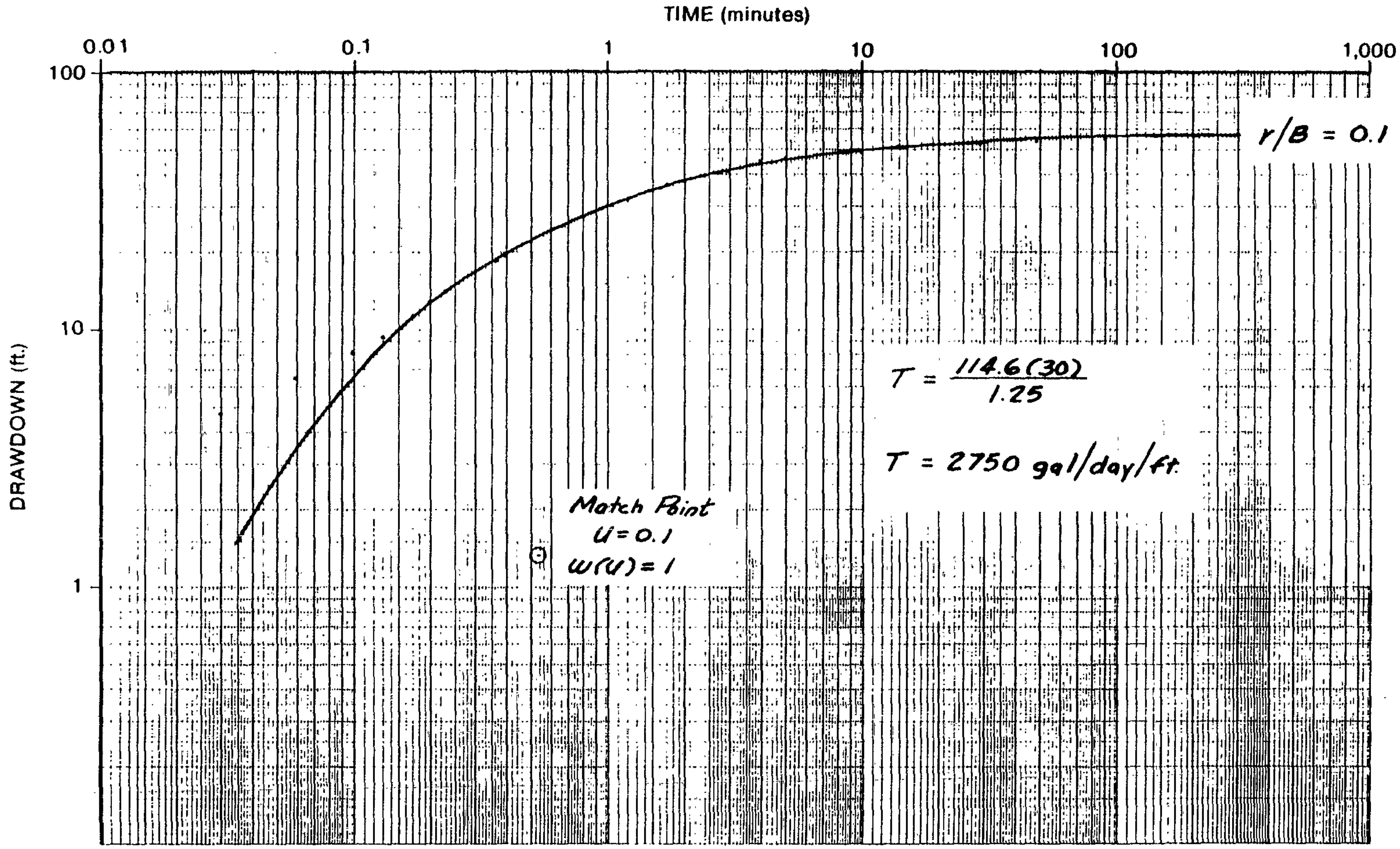
AR301181



JACOB'S METHOD
1st TEST, MW-3B

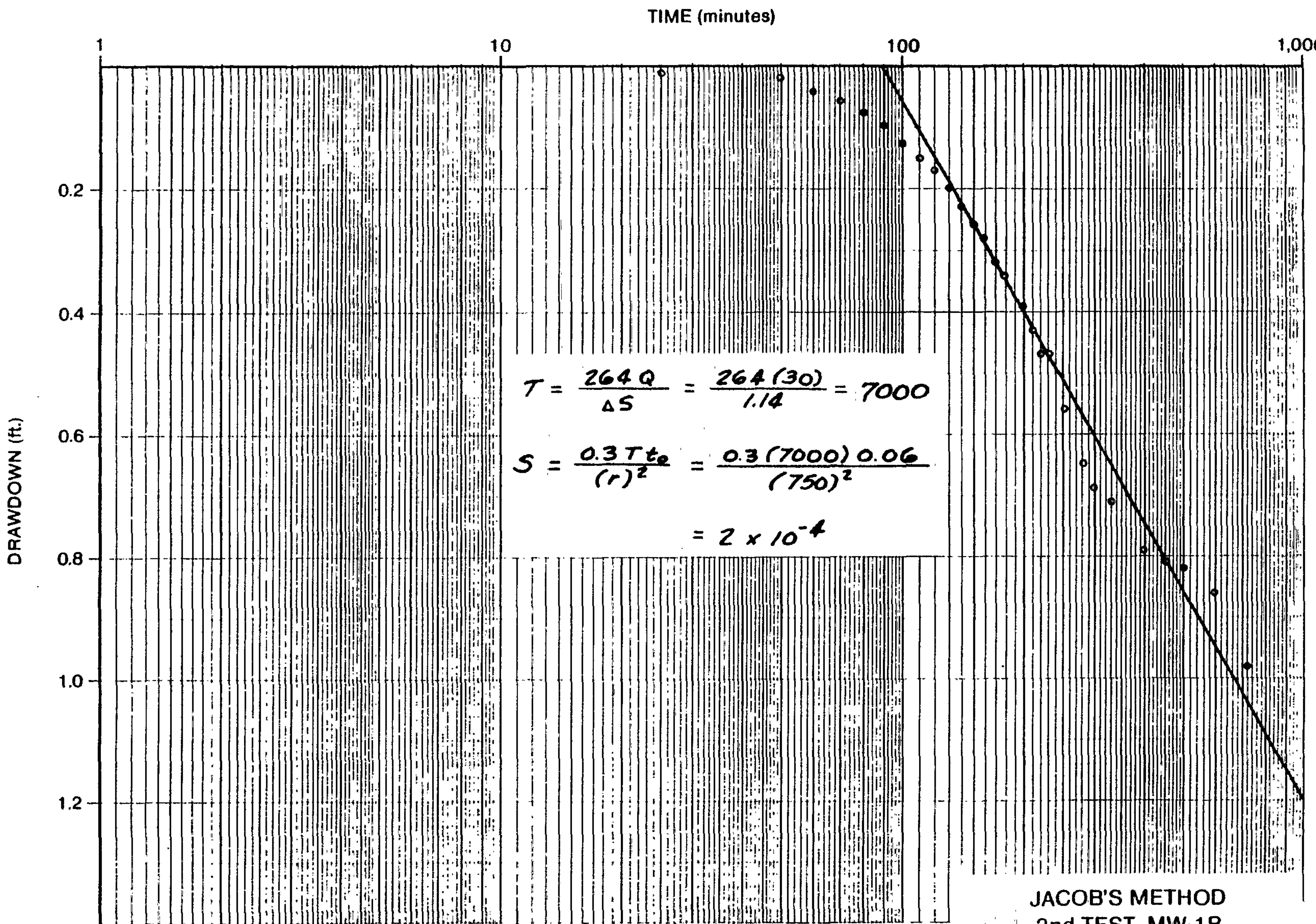
FIGURE

AR301182



PRICKET - BOULTON METHOD
2nd TEST, MW-3B

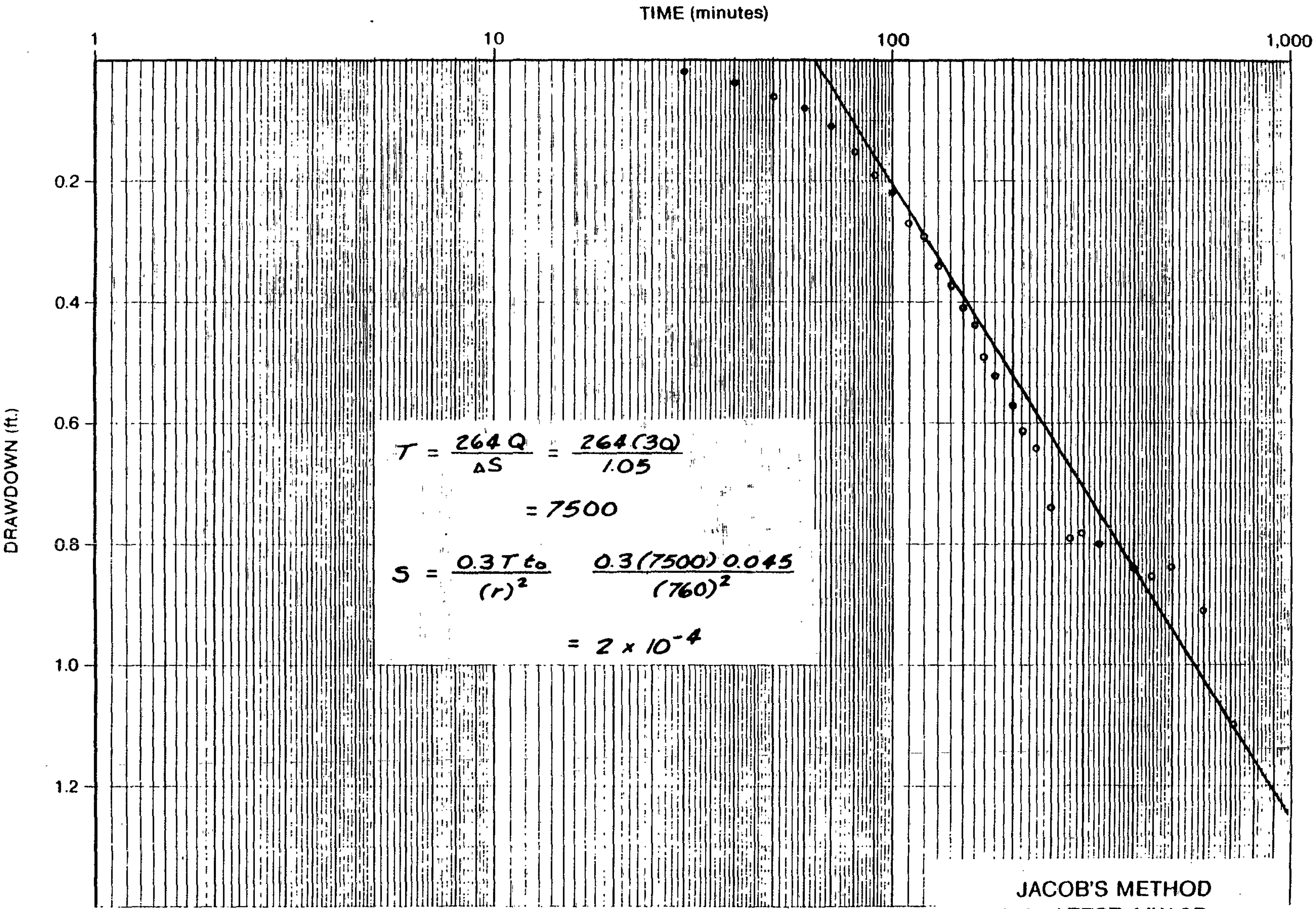
FIGURE (



JACOB'S METHOD
2nd TEST, MW-1B

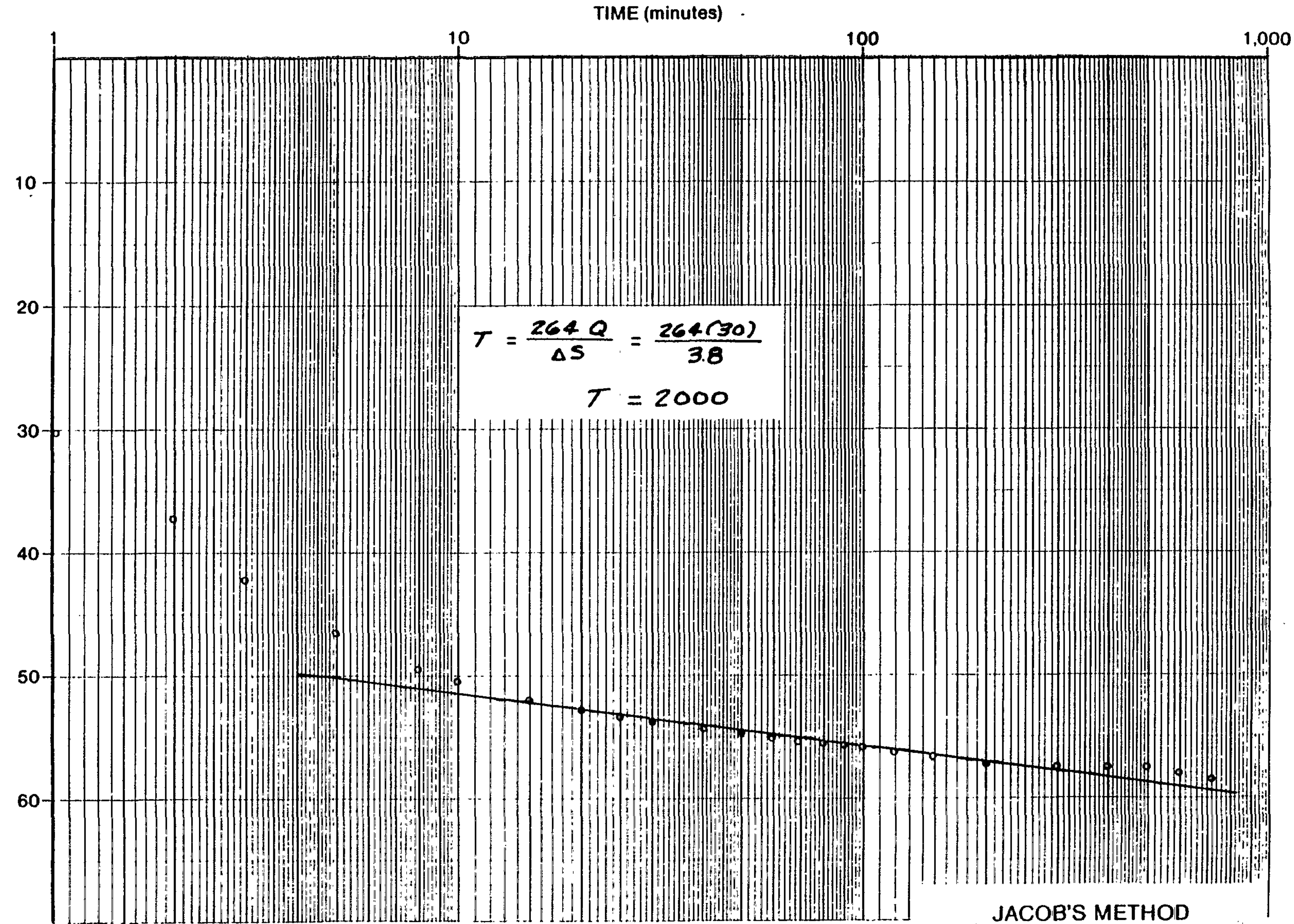
FIGURE

AR301184



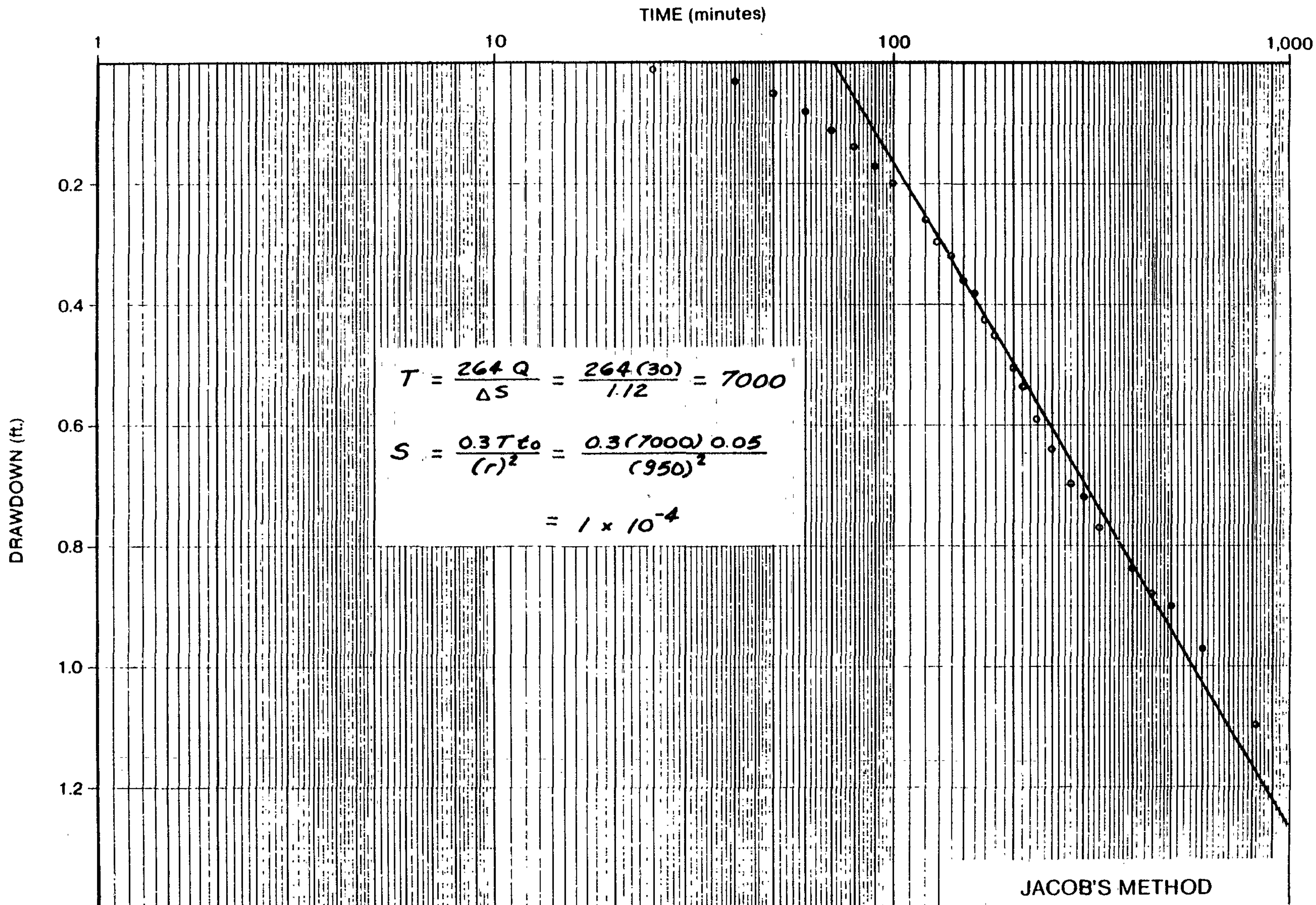
JACOB'S METHOD
2nd TEST, MW-2B

FIGURE



JACOB'S METHOD
2nd TEST, MW-3B

FIGURE



JACOB'S METHOD
2nd TEST, WW-13

FIGURE 10

AR301187

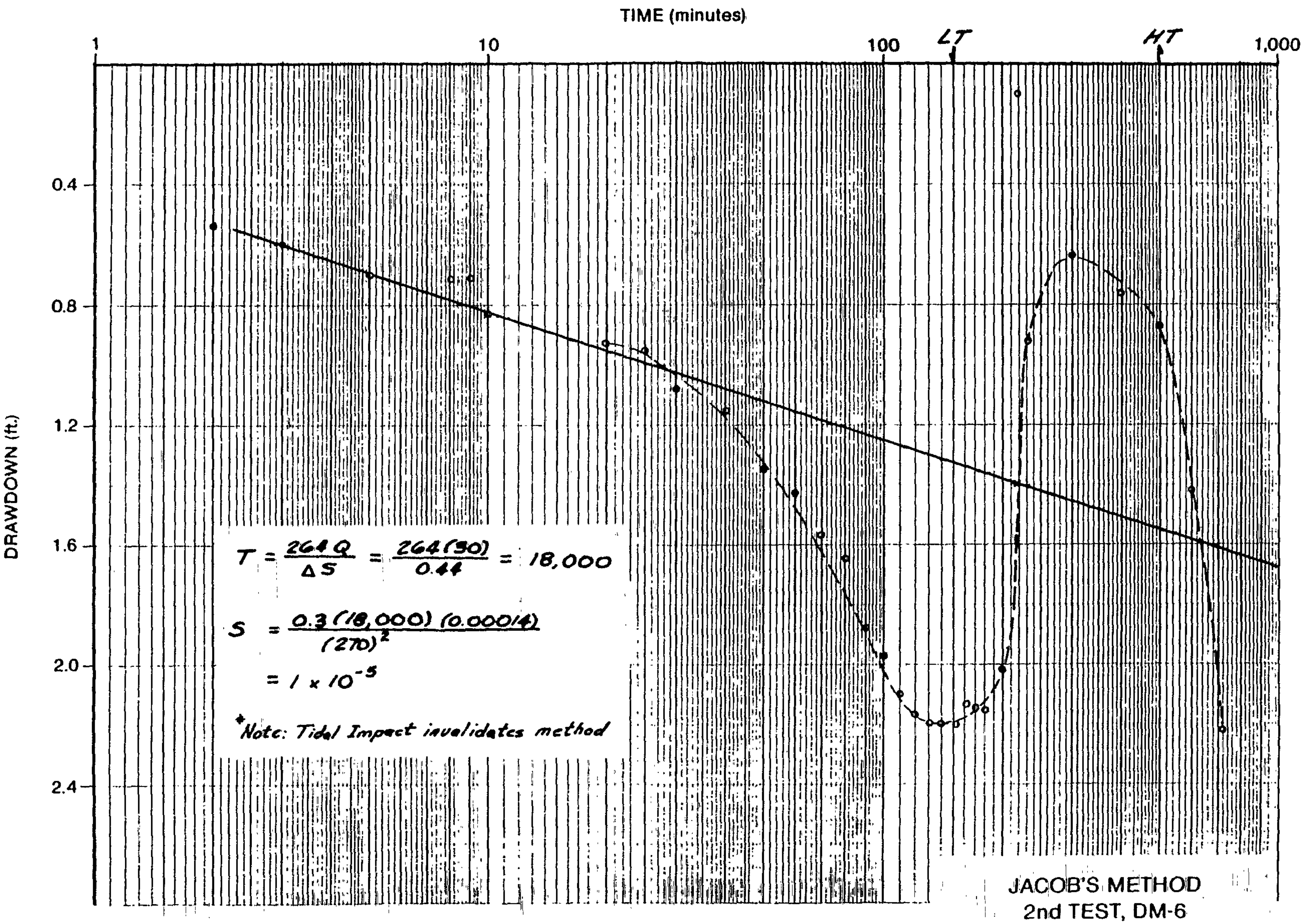


FIGURE 1

AR301188

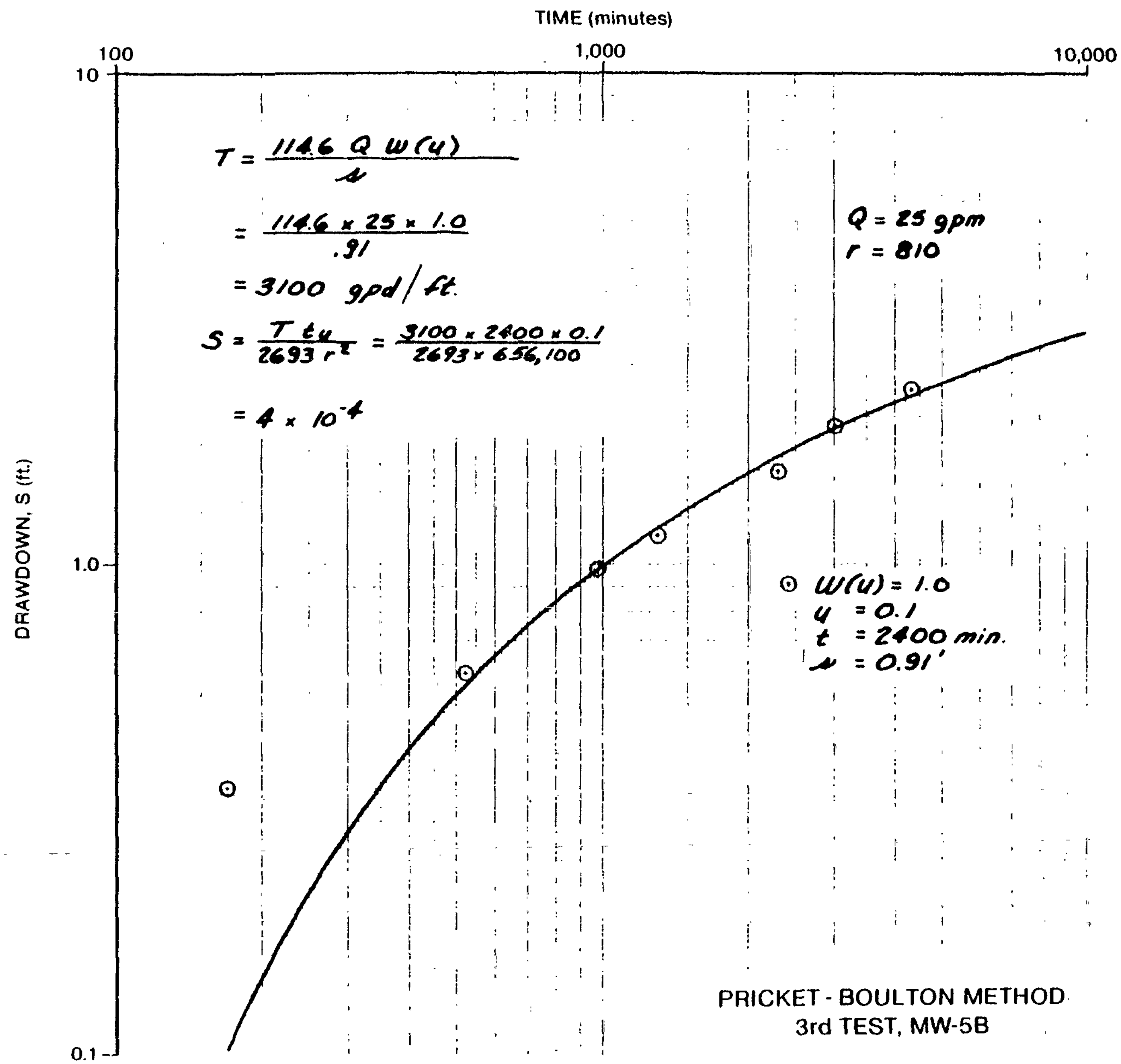


FIGURE 12

AR301189

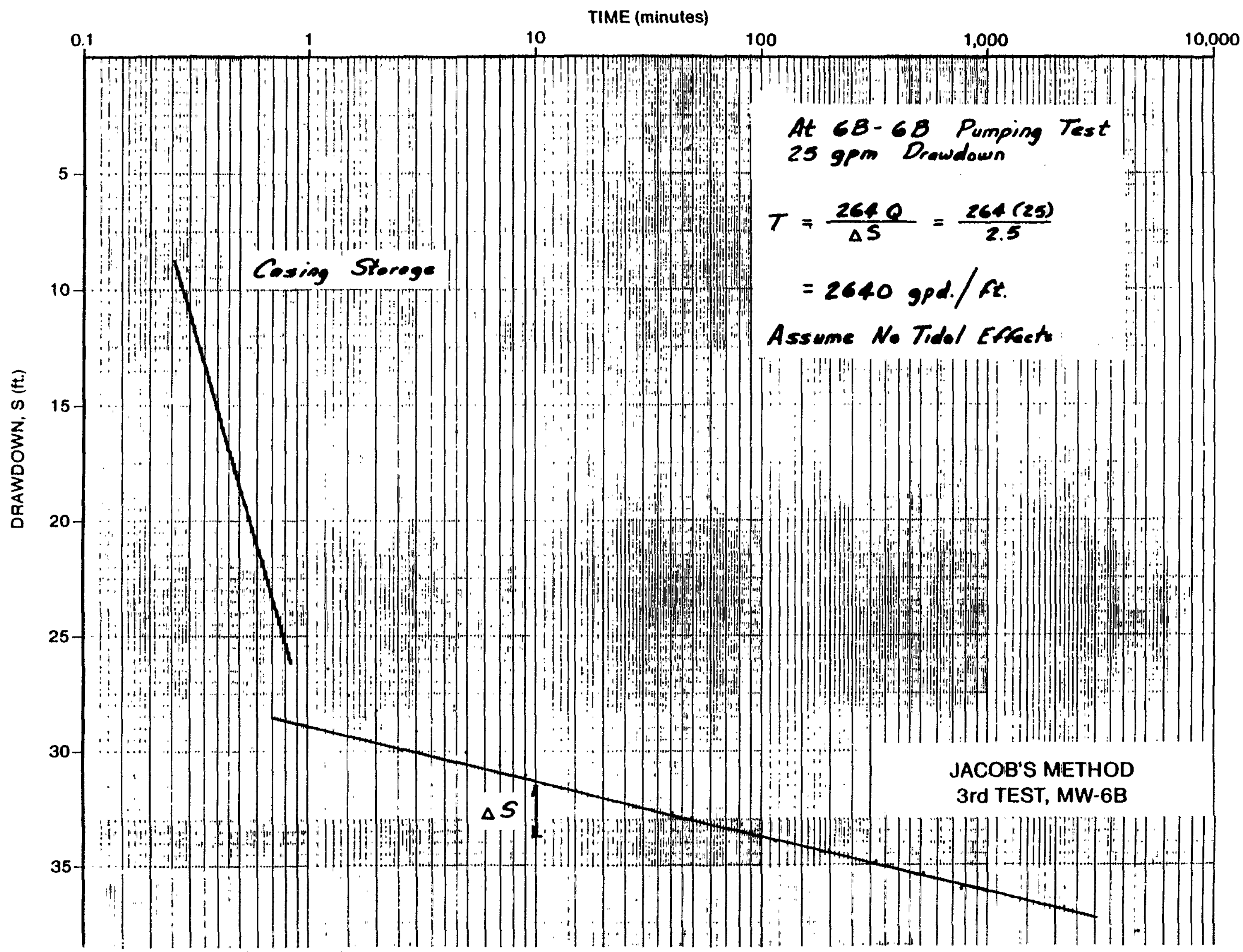
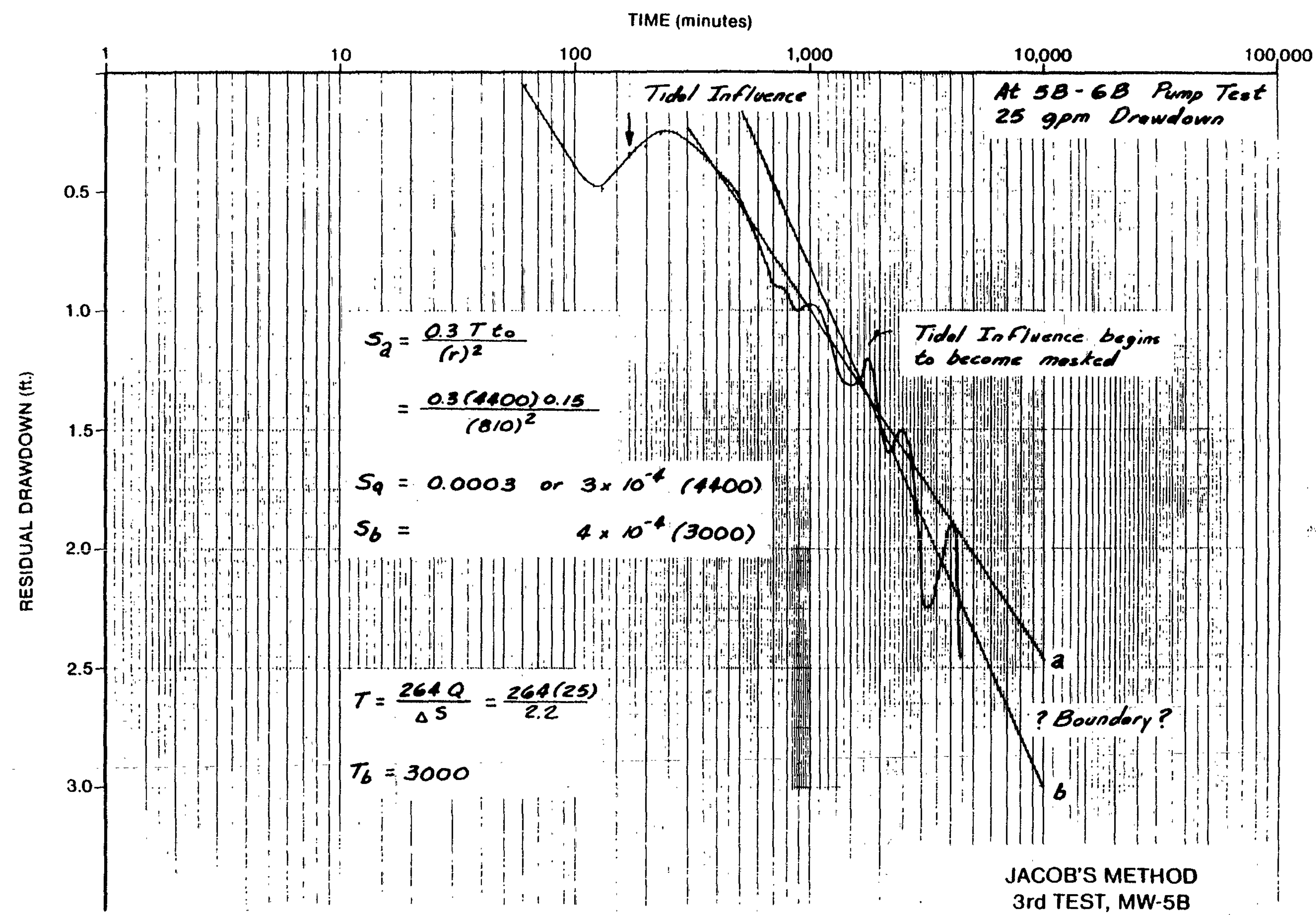


FIGURE 13

AR301190



JACOB'S METHOD
3rd TEST, MW-5B

FIGURE 14

AR301191

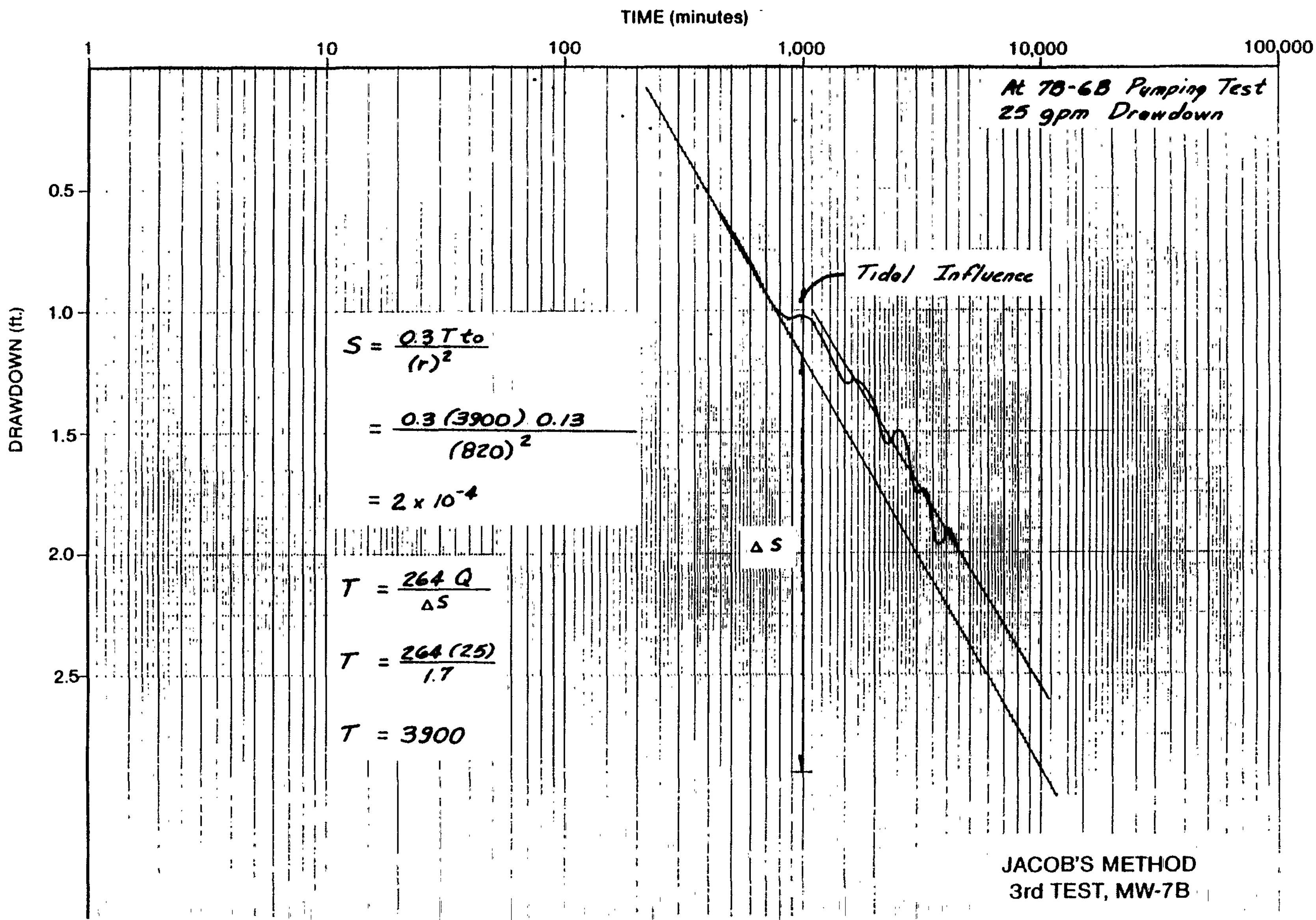


FIGURE 15

AR301192

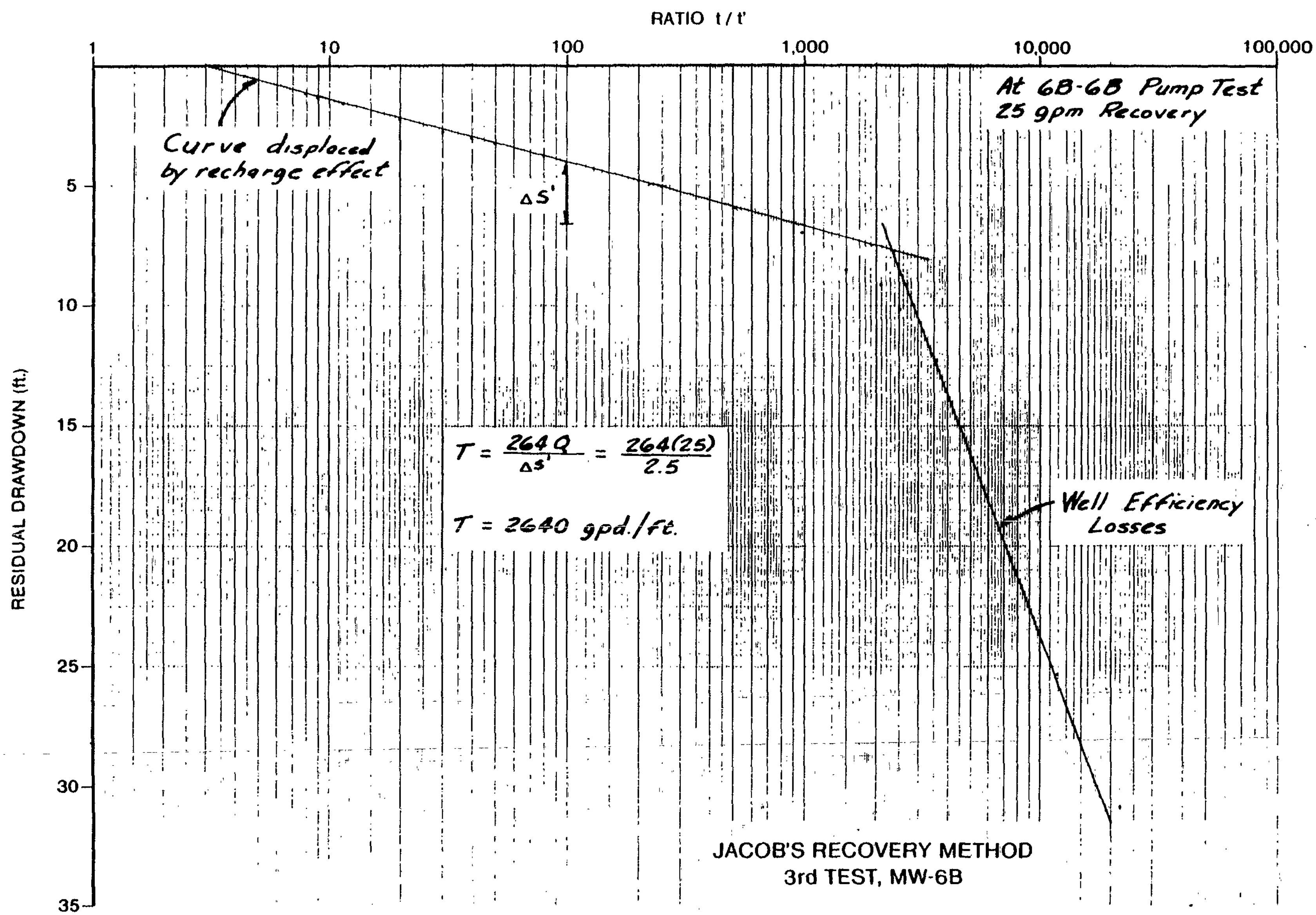


FIGURE 16

AR301193

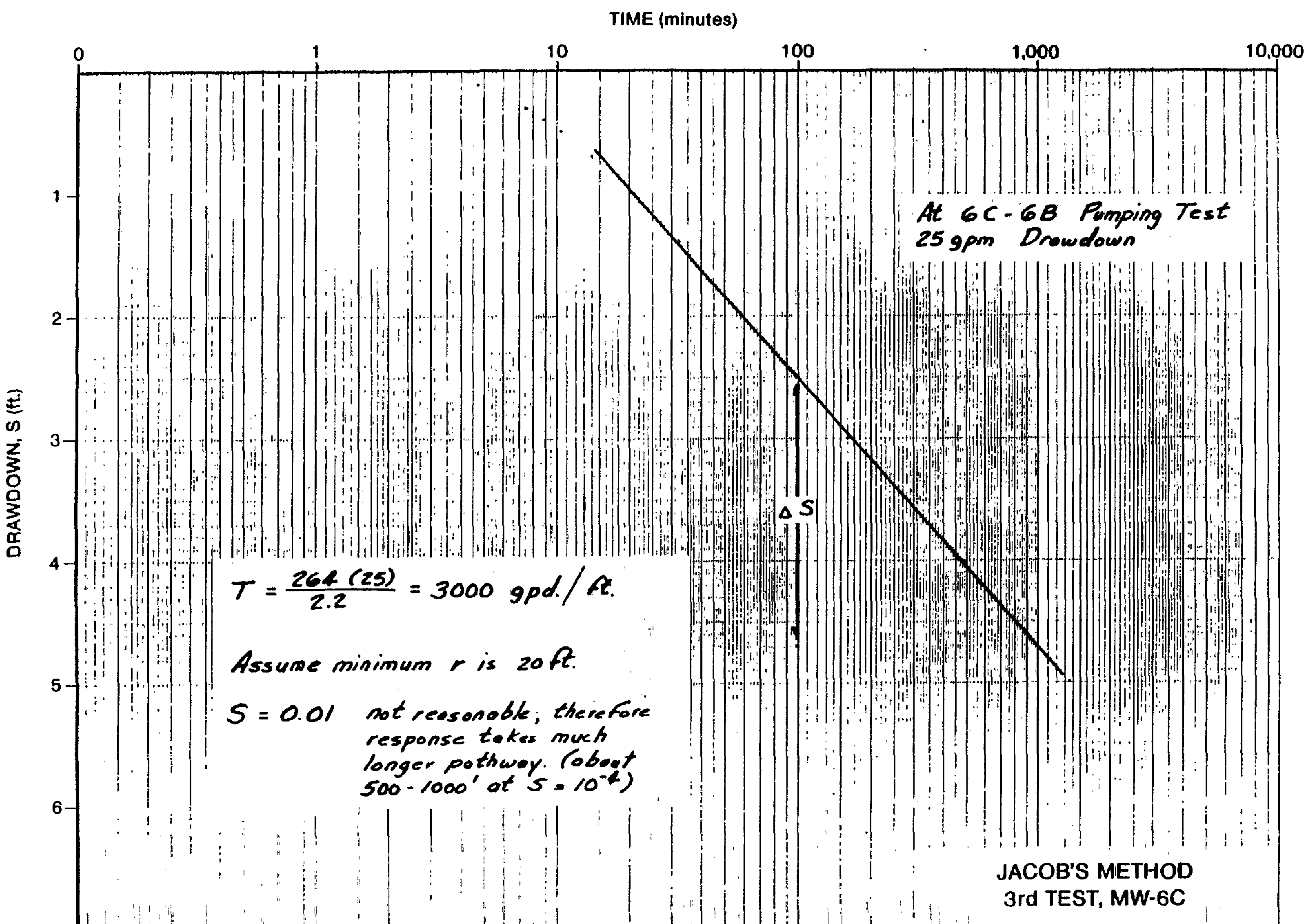
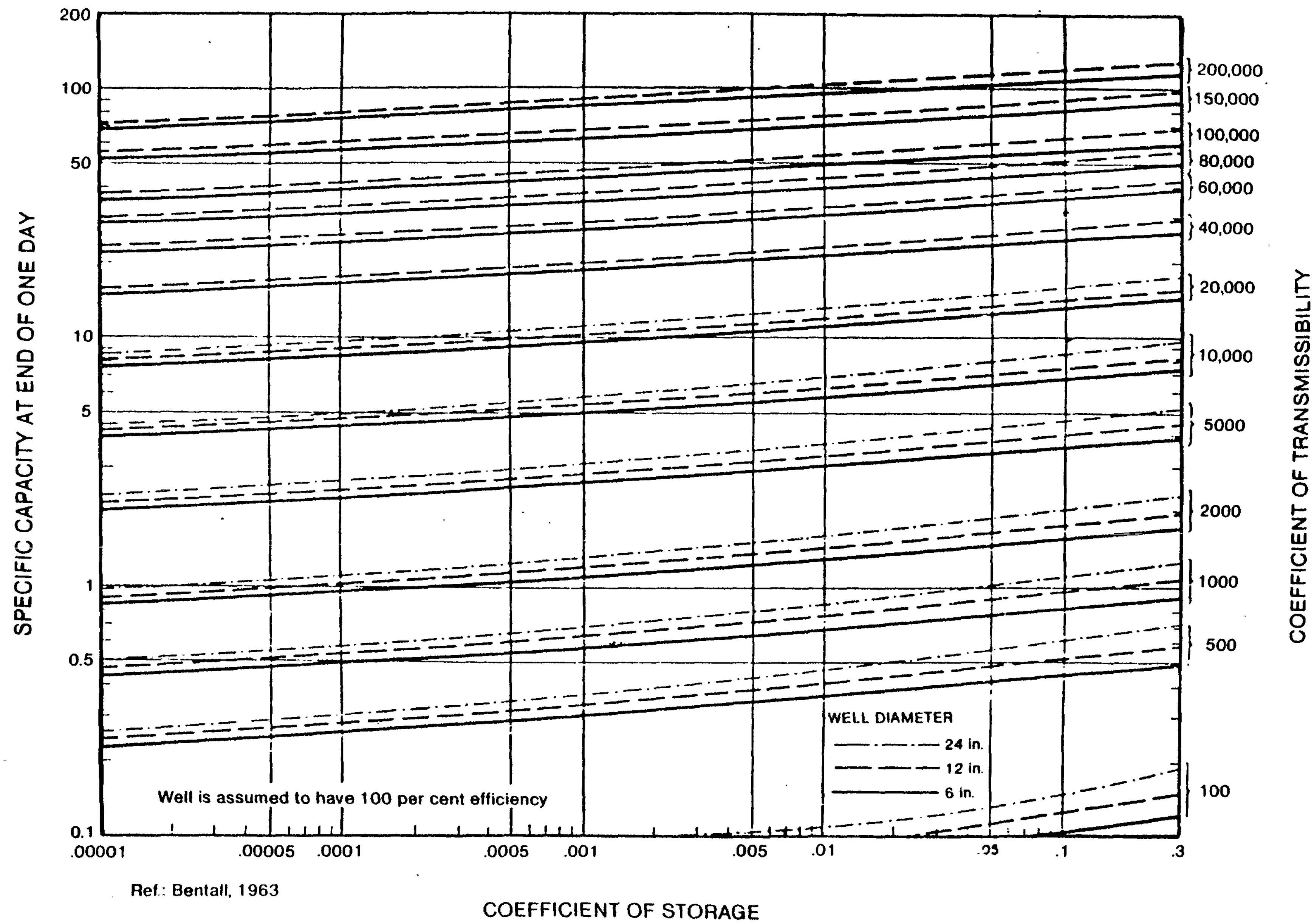

TIME (minutes)
0
1
10
100
1,000
10,000
DRAWDOWN, S (ft.)
1
2
3
4
5
6
At 6C-6B Pumping Test
25 gpm Drawdown
ΔS
T = 264 (25) / 2.2 = 3000 gpd./ft.
Assume minimum r is 20 ft.
S = 0.01 not reasonable; therefore response takes much longer pathway. (about 500-1000' at S = 10^-4)
JACOB'S METHOD
3rd TEST, MW-6C

FIGURE 1

WELL AQUIFER RELATIONSHIPS



Ref.: Bentall, 1963

FIGURE 18

APPENDIX D-1

DATA LOGGER AND AQUIFER TEST CHRONOLOGY:

July 29, 1987

- Start recording from some channels on DL-1 (all except well number 1C)

July 31, 1987

- Transducer Accuracy Check (except well cluster number 4 and DM-4)
- Discover bad data logger (DL-3) (still logging, however). Also discovered that transducer in SM-2 not operating.
- Data loggers dumped onto computer discs.

August 3, 1987

- New data logger setup at DL-3 location.
- New 5 psi transducer put into SM-2
- Discover transducer cable to WW-13 chewed through by rodent
  - 5 psi transducer pulled from MW-7A and set into WW-13
- 15 psi transducer replaces 5 psi transducer in MW-7A.
- Step down test at MW-3B

August 4, 1987

- Transducer Accuracy Check for all wells (except MW-3B)
- Electric problems for start of first pump test.

August 5, 1987

- Setup new electric line to pump
- Heavy rainstorm (start approximately 5:00 pm ?)

<u>August 6, 1987</u>

- Pump test No. 1 <u>Start at 7:30</u>
- Collected round of water level measurements
- DL-1 and DL-2 dumped

<u>August 7, 1987</u>

- DL-3 dumped.
- Collected round of water level measurements.

<u>August 8, 1987</u>

- Roger Henning Site Visit (Dumps DL-4 plus ?)

<u>August 9, 1987</u>

- Tide transducer appears to be floating but tide too high to repair.
- Collected round of water level measurements.

<u>August 10, 1987</u> - Start of Water Sampling

- Pump Test No. 1 OFF at 11:30
- Repair tide gage transducer (late in day)
- 15 psi transducer pulled from MW-7A put into tide casing (approximately 19:00 Hrs ?).
- Discover transducer in SM-1 giving false readings.

<u>August 11, 1987</u>

- Start pump test No. 2 at 7:30.
- Pump test No. 2 OFF at 19:30.

<u>August 15, 1987</u>

- Water sampling finished.

<u>August 19, 1987</u>

- Setup for pump test No. 3
- Move DL-1 to DL-2 position re-label DL-2 (some channels change)
- Move DL-2 to DL-5 position and re-label DL-5
- Discover that transducers that were in MW-7C and MW-7B and MW-5A and MW-5B were not in wells (apparently removed during water sampling)
- Transducer placed into MW-7A
- Step down test at MW-6B

<u>August 20, 1987</u>

- Transducers placed into MW-5A and MW-5B and MW-7B and MW-7C.
- Dumped data from DL-1/DL-5 and from DL-1/DL-2
- Transducer Accuracy Check for all changed transducers and data loggers

<u>August 21, 1987</u>

- Pump test No. 3 start at 9:00

<u>August 24, 1987</u>

- Pump test No. 3 OFF at 10:30
- Collected round of water levels

<u>August 25, 1987</u>

- Start to pack up data loggers and transducers